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PLATE I.

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GENTH'S TYPES!

In the purchase of a large lot of specimens, constituting the pick of everything of historical or specimen value, in the collection of the late M. E. Howell, we are able to afford our customers a rare opportunity to acquire certain choice things possessing unusual merit. These are no less than the original specimens (or portions of them) described by the late Dr. F. A. Genth, and later presented to Mr. Howell. Many are excellent crystallizations, others mere fragments. The collection covers the period about 1860–95 and includes, besides this series of "notables," many fine European things gathered by Mr. Howell and his brother Prof. S. B. Howell, who formerly occupied the chair of Mineralogy in the University of Pennsylvania. There are few duplicates and the distribution of the collection will be as rapid as that of the "Trautwine," of which there is little of importance remaining. The labels are scientifically exact, the words "Genth Type" in Prof. Howell's handwriting being not infrequent.

☞ Send us your desiderata list, as some of your wants are doubtless in the collection, though not enumerated here. The following list may be "a word to the wise" as to the character of the collection, and the advisability of writing at once.

A Few Typical rarities from the Howell collection:

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Amalgam,
Arquerite,
Dyscrasite,
Huntilite,
Domeykite,
Tin,
Palladium,
Pentlandite,
Whitneyite,
Chilenite,
Hessite,
Altaite,
Naumannite,
Lehrbachite,
Zorgite,
Stromeyerite,
Sternbergite,
Polydymite,
Grunauite,
Linnaeite
Carrollite,
Barnhardtite,
Lillianite,
Rammelsbergite,
Volzite,
Livingstonite,
Rezbanyite,
Sartorite,
Galenobismutite,
Alaskaite,
Miargyrite,
Plagionite,
Binnite,
Dufrenoysite,
Schapbachite,
Bjelkite,
Freieslebenite,
Wittichenite,
Aikinite,
Pyrostilpnite,
Rittingerite,
Geocronite,
Lautite,
Zanthoconite,
Tysonite,
Matlockite,
Mendipite,
Schwartzembergite
Percylite,
Tallingite,
Fluellite,
Bismite,
Stetefeldtite,
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Alexandrite,
Brucite,
Parisite,
Thermonatrite,
Liebigite,
Castorite,
Barsowite,
Babingtonite,
Uralite,
Riebeckite,
Tritomite,
Meliphanite,
Kaliophilite,
Hortonolite,
Knebelite,
Dioptase,
Stolzite,
Romeite,
Guarinite,
Johannite,
Hielmite,
Cale[illegible]ite,
Re[illegible]hyllite,
P[illegible],
Somervillite,
Apthitalite,
Bergmannite,
Trögerite,
Phosphuranylite,
Rhabdophanite,
Woodwardite,
Fauserite,
Volborthite,
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SIX WEEKS IN TASMANIA

and a careful search on the part of our collector for good things—purchasable, exchangeable or collectable, yielded a large consignment just in. It includes: Two specimens of the rare **"Dundasite"**; a lot of neat cabinet size specimens of **Stannite** (practically unknown except from Cornwall, until our introduction of this find). A lot of the new type of dark brown, brilliant **Axinites,** of larger size than formerly seen.

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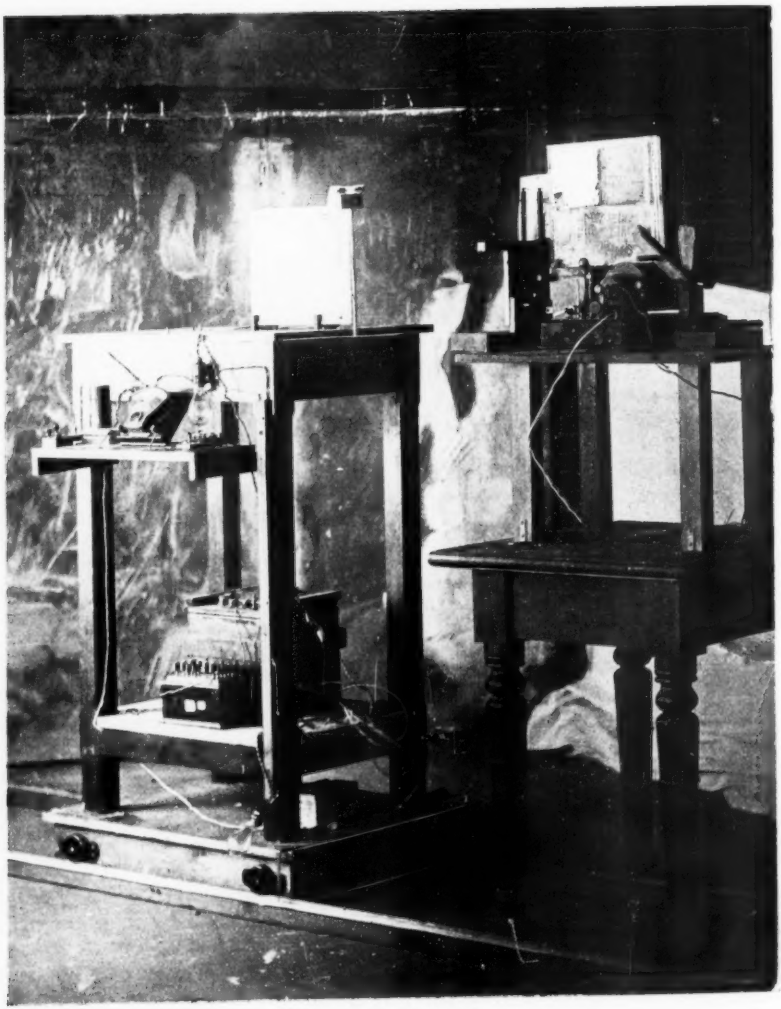


THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. I. — *Velocity of Electric Waves in Air;* by G. V. Maclean. (With Plate I.)

Hertz determined the wave-length of electric waves in air in one of his experiments to be 9·6 m., with an anti-node 70 cm. behind the reflector. In the case of electric waves along wires he found the rate of propagation to be $2{\cdot}8 \times 10^{10}$ cms. per sec. He further proved, if slow oscillations were used, that the lengths of the electric waves along wires and in air without wires would differ, but if rapid oscillations were employed the lengths of the waves would be the same. The truth of this has been confirmed by J. J. Thomson and Lecher.

E. Sarasin and de la Rive* concluded from their experiments that the wave-lengths determined are independent of the dimensions of the oscillator and vary with the size of the resonator employed. They showed that the rate of propagation of electric waves through air without wires is sensibly the same as that along wires. Thus by using a resonator 26 cms. in diameter the length of the internode along wires was 1·12 and in air between 1·12 and 1·25 m., while a resonator 36 cm. in diameter gave the lengths to be 1·47 m., air between 1·4 and 1·8 ms. respectively. They claimed that the same oscillator gives rise at the same time to waves of different lengths, that the waves sent forth are not simple, but are complexes of an infinite number of different waves, in fact a continuous electrical spectrum is formed, and that the resonator used acts as an analyser picking out from the spectrum those waves whose period is peculiar to itself, and to these alone it responds.

* Bibliothèque Universelle, Archives des sc. phys. et nat., 3° period, xxiii, No. 2, 1890, p. 113. Also p. 557.

Poincaré* and Bjerknes,† independent of each other, contended that the oscillator and resonator each set up their own vibrations, which are not necessarily related, and that the variation of the wave-length, when different resonators are used with the same oscillator, is not due alone to multiple resonance, as stated by Sarasin and de la Rive, but to the unequal rate of damping of the waves by the resonator and oscillator. If the rate of damping in the resonator is small in comparison with that of the oscillator, then Sarasin and de la Rive's theory holds; if, however, the rate of damping of the resonator is great in comparison with that of the oscillator, Sarasin and de la Rive's theory fails. The length of the internode does not alter when the same oscillator is used with resonators of different sizes, but it varies with the dimensions of the oscillator when the same resonator is employed; the wave-length being the same as is found when a method is employed in which no resonator is needed. "If the rates of damping of the oscillator and resonator are almost the same, the lengths of the waves they produce exercise the same influence upon the length of the internode measured."

Sarasin and de la Rive had also pointed out the necessity of having the oscillator and resonator in tune with each other, and more particularly so was this needful when the waves in air without wires were measured.

In the experiment about to be described, a new method was employed by which the direct determination of the period of the oscillator was found. The oscillator and resonator were tuned by using a special form of self-induction and capacity and balancing them. The resonators used by Hertz, and by the other physicists to whom reference alone has been made, were simple loops of copper wire which acted as the self-induction, while the capacity was two small metal spheres. The oscillators had very large capacities in comparison with those of the resonators.

In our experiment the form and size of oscillator and resonator, as also the dimensions of their self-inductions and capacities, are identical. The resonator here used is a specially devised coherer. Many attempts of late have been made to successfully employ the coherer to measure electric waves. The results have generally been to stamp the coherer as an instrument too capricious for such work. In this connection may be mentioned the work of Professor Murani.‡ He used a

* Poincaré, Elektricität und Optik, 1891. Archives des sc. phys. et nat, xxv, p. 609, 1891.

† Bjerknes, Wiedemann's Annalen. Band xliv, p. 75, 1891.

‡ Studio della onde stazionarie di Hertz col mezzo di un coherer, del Prof. O. Murani del R. Istituto Lombardo. Milano, 1898.

Marconi coherer and a galvanometer. The readings of his galvanometer, as he moved the coherer farther and farther from the reflector, changed; no zero readings, however, were found and there was no regular increase or decrease in the readings. The following table is taken from his paper:

Distance of Coherer in cms. from Reflector.	Deflection of Galv. Needle.	Distance of Coherer in cms. from Reflector.	Deflection of Galv. Needle.
2	12	60	15·4
5	13·4	65	16·0
10	16·2	70	17·0
15	16·3	75	16·5
20	16·4	80	16·2
25	15·5	90	15·8
30	15·8	100	16·2
35	15·5	110	16·5
40	15·8	120	16·0
45	15·5	130	16·3
50	15·5	140	16·4
55	16·0	150	17·2
		200	17·4

His results were submitted to Professor A. Righi, who with Professor Murani, concluded that the coherer was unsuitable for the measurement of stationary electric waves.

Le Royer and Paul von Bërchem* at Geneva, in April of 1894, used a coherer containing iron filings kept between two magnetized needles. Their results showed that the tube they employed had not a wave-length peculiar to itself and that it acted as an analyser and not as a resonator, and that it would serve to measure the electric wave-lengths in air.

The coherer here employed is one reduced to its elements. It might in fact be termed an electro-bolometer, and in general is not more difficult to use than the heat-bolometer.

Two globules of platinum, one mm. in diameter, are attached to the ends of two platinum wires 0·12 mm. in diameter and 1·7 cm. in length. These latter form spirals each of two convolutions about two iron terminals 1·5 mm. in diameter and 4 cm. in length. These terminals run through the center of the two brass caps of a glass tube 8·5 cms. long and 1·5 cms. in diameter. To one of the terminals was connected a mill-head screw, so that the platinum globules could be adjusted to any distance from each other. This constitutes the coherer proper. The glass tube is not exhausted; it serves merely to protect the globules from dust, dampness, or other external interferences. The coherer is placed in circuit with a large Volta-

* Bibliothèque Univ. Archives de Genève, xxxi, 1894, p. 558.

Pavia battery of peculiar construction giving a steady current, a resistance box in which a resistance of over 100 ohms is always kept, and a Direct Reading Mille-Ampère meter. The current is shunted by a suitable resistance before passing through the coherer.

The capacity and self-induction of the coherer are respectively two sheets of tin foil 14·5 cm. by 14·1 cms. shellacked to the sides of a glass plate 30·4 cms. long, 30·4 cms. wide and 5 cms. thick, and two copper wires 9·62 cms. long, and ·3 mm. in diameter, parallel to each other and distant 5 cms. These two wires had two of their ends soldered to two strips of brush copper which latter made close contact with the tin foil, by means of hard wax; the other ends passed into two small binding posts on the caps of the coherer. The current through the coherer is governed by a key. This constituted the coherer or receiving circuit. All the wires used throughout the whole experiment were well insulated, twisted and kept as far as possible out of the direct course of the electric waves, so that any influence the wires might exert upon the results was reduced to a minimum.

The different parts of the coherer circuit can be seen in the photograph, Plate I.

The platinum globules were first brought into the slightest possible contact by carefully adjusting a micrometer screw. When such a contact had been effected was known by watching the motion of the Mille-Ampère meter needle. Upon causing a train of electric waves to pass the coherer, the resistance of the latter is lessened by the globules moving into closer contact, that is to say the globules are made to cohere. This augmentation of the globules is instantly evidenced by the increased throw of the Mille-Ampère meter needle.

The coherer here employed is the outcome of a great many experiments with Lodge coherers, Marconi coherers or Branly tubes. Tubes containing metal filings of all kinds and of different degrees of fineness, as iron, silver, platinum, copper, zinc, nickel, magnesium, brass, granulated arc carbon with copper, or brass, or iron terminals, either magnetized or non-magnetized, all proved to be unsuitable for measurement of the electric wave-lengths, in not possessing the proper degree of sensitiveness. They all had the common fault of not allowing the Mille-Ampère meter needle to return quickly to its zero reading. Decohering of the coherer in the present form is accomplished almost instantly by the elasticity of the platinum spirals, upon opening the circuit key. No tapping is required as in other kinds of coherers. In fact this form of a coherer alone of all tried gave good working results. Moreover, the above coherer at once shows the manner of action of

the ordinary metal filings coherer. The platinum globules are brought into slightest contact, the passage of an electric wave causes the globules to cohere more closely; thus the resistance to the battery current through the coherer is lessened, as is shown by the increased deflection of the needle. The cohering of the metal filings (in this case the two globules) seems to be due to an electrostatic effect produced upon them by the passage over them of the electro-magnetic waves. Further evidence of this will be given later.

Before concluding the description of the coherer, it will be of advantage to give an account of the oscillator circuit and its accessories.

The electric spark which sent forth the trains of electro-magnetic waves through the free air between the oscillator and coherer, was given out by a large Ruhmkorff coil in connection with a storage battery of 27 cells in parallel with a voltage of about 55.

The oscillator consisted of two platinum globules 1 mm. in diameter attached to the ends of a platinum spiral making two convolutions about copper terminals, exactly like those in the coherer. This oscillator was placed in the secondary spark gap of the Ruhmkorff coil. The oscillator globules were always kept 4 mms. apart from each other. The same kind and the same amount of capacity and self-induction were used as in the coherer circuit. The coherer and oscillator circuits were thus tuned to one another.

The primary spark-gap of the Ruhmkorff coil was removed to a distant mercury break. The mercury break was of special construction. Three storage cells drove a motor, which in turn caused a plunger to play in and out of a mercury glass cup. On opposite sides of the glass cup were secured a glass tube shoulder, 1 mm. or so above the level of the mercury. To these glass shoulders were attached rubber tubes, one leading from a water tank and the other to a sink. Water was siphoned from the tank through the glass cup, over the surface of the mercury. Thus the surface of the mercury was always clean. A pinch-cock was fixed to the first rubber tube so that the strength of the stream of the running water could be regulated and kept constant. When the stream of water was properly regulated, sparking at the oscillator could be continued for hours at a time, the sparks always being perfectly regular and uniform. Before the addition of the stream of water over the surface of the mercury, the break gave endless trouble, needing attention almost every two or three minutes, but under the conditions adopted it required very little attention. However, care had to be taken to prevent a too free flowing of the water, for otherwise the nature of the

sparking at the oscillator was much altered, too much water acting like too little. Wires ran from the break to the Ruhmkorff coil and also to a key at the coherer carriage. Thus from the coherer carriage one could control both the coherer and oscillator circuits.

The various parts of the oscillator circuit are shown in Plate I.

The motor and break were enclosed in a double box, the space between the two boxes being packed with felt. This was done in order to deaden the noise of the motor and primary sparking. Such a proceeding is not essential to the good working of the coherer, but it enables one to detect at once by the ear any variation in the secondary sparking. It thus leaves the eyes free to observe the movements of the Mille-Ampère meter needle. One soon became accustomed to the characteristic crackling sound of the kind of sparks required and accordingly hardly ever needed to look at the oscillator. The sparks produced at the oscillator must be continuous and always the same, otherwise the waves set up will differ from each other and consequently the Mille-Ampère meter needle readings will vary so irregularly as to be absolutely worthless. Sparks of the same nature must therefore be produced at all times during the experiment. This is rendered possible by the employment of the continuous stream of water over the surface of the mercury in the mercury cup of the break.

The coherer and its capacity were mounted upon a stand, carried upon a carriage which could be easily moved along a graduated track. It was possible to make a change in position of the carriage as small as ·25 mm. To the side of the carriage was firmly secured a shelf which supported the keys of the two circuits, the shunt resistance and the Mille-Ampère-meter. The lower part of the carriage held the battery and its resistance box.

If the coherer be placed in any part of the room, it responds to the sparking of the oscillator, but in some positions more strongly than in others. It thus appeared desirable to place the oscillator within a completely closed metal box, with a window in its front side. This proved beneficial, since it caused the waves to be less scattered at the instant of leaving the oscillator, confining them more to that region of the room where the experiment is conducted, than elsewhere. The metal box then acts, as it were, like a megaphone. The front of the box was on hinges and could be left open at pleasure. The inside of the metal box was put into metal connection with the gas pipes of the room. At one end of the room was placed the oscillator, while at the opposite end was fixed a metal reflector which was connected by wires to gas pipes and

water pipes. In the free space between the oscillator and reflector moved the coherer carriage. The dimensions of free space between the reflector and oscillator were 12·67 m. in length, 6·15 m. in width and 5·14 m. in height. The nearest wall had five windows, each 1·66 m. by 1·12 m. The reflector was of sheet tin 3·32 m. wide by 4·24 m. high.

The oscillator, the coherer globules and the center of the reflector were always kept in the same horizontal line. The oscillator and coherer were thus 2·25 m. above the floor, 2·89 m. below the ceiling and 1·57 m. from the nearest wall, which ran the full length of the room. By moving the carriage to and fro, the coherer was always in the same horizontal line at any desired distance from the reflector.

The coherer carriage was moved to any distance from the reflector, its globules being put into slightest contact, then the coherer circuit was closed by touching the coherer circuit key and the Mille-Ampère meter needle reading taken. Upon touching the key in the oscillator circuit, sparking at the oscillator began, the electric waves traversing the free space act upon the coherer and at once there is or is not an increased reading given by the Mille-Ampère meter needle. By moving the carriage to different distances from the reflector and repeating the above operations different readings are found. There is seen to be a regular increase and decrease in the Mille-Ampère meter needle readings as the coherer is moved farther and farther from the reflector. At certain places no change in the readings is observed, while at certain other places there is a maximum reading. Thus by means of the coherer we are enabled to locate the nodal and antinodal points of the electric waves, and hence we determine the wave-length. Many precautions had to be taken during the conduction of the experiment. The coherer responds to any (secondary) electric spark, the Mille-Ampère meter readings differing for different kinds of sparks. Not only will the coherer respond to the sparks from the oscillator, but it responds to any other (secondary) spark which at the time may have taken place in any other part of the building or on a distant trolley wire. So sensitive is the coherer, the slightest jarring of the room, such as caused by the slamming of a door or of the walking of persons in the corridor, will be sufficient to very materially confuse the readings. Satisfactory and reliable measurements can only be made when such disturbing causes are not present. Accordingly the night hours were selected in which to carry on the observations. If the mercury in the mercury cup of the break becomes coated, the nature of the secondary spark changes and so the readings under such conditions are not proper. If a too strong current be sent up from the storage battery into the

Ruhmkorff coil, the nature of the secondary sparks change so much that the readings must be disregarded. The greatest care had to be exercised to preserve the equality of the oscillator sparks, throughout the whole of the measurements.

It was further noticed, whenever the key of the oscillator circuit was closed (the coherer key being first closed), there was always a very distinct increase in the Mille-Ampère meter readings even before the sparking at the oscillator began. However, as soon as the sparking at the oscillator commenced, this increased reading was augmented more or less according to the distance of the coherer from the reflector. This peculiar motion of the needle before the sparking begins at the oscillator seems to point to an electrostatic effect upon the coherer globules, due to electric or magnetic causes proceeding from the oscillator and preceding those oscillations which give rise to the stationary waves; whatever the cause may be, it has the effect of lessening the resistance between the coherer globules. This phenomenon would appear to throw some light upon the real cause of the action of a coherer. It shows that the metal particles are attracted nearer to each other and there held in contact by the electrostatic effect produced upon them by the passage of the electric waves. Such an effect being different at different distances from the reflector, and most marked near the oscillator, would very much alter the readings as really given by the wires we are endeavoring to measure. Accordingly this effect had to be eliminated. The elimination was thus accomplished. Upon first closing the coherer circuit and allowing the needle to come to rest and then closing the oscillator circuit, the above described phenomenon having taken place, the sparking at the oscillator was continued for a few seconds, causing the needle to creep up to a maximum reading. Then the oscillator circuit was opened and the coherer circuit was opened and closed four or five times in succession; each time the needle returned to the above determined maximum reading. Next the coherer circuit was opened, the oscillator circuit closed, while the sparking was continued for some time, and finally the coherer circuit was closed. The above determined maximum reading of the needle is in all cases (except when the coherer is at a node) augmented, the amount of this augmentation increasing or decreasing as we move away from the reflector towards the oscillator. It is only such waves as the vigorous and prolonged sparking at the oscillator sets up and maintains that are able to increase the first determined maximum reading. Thus the effects of the above observed phenomenon are obviated, since they are powerless to alter the first-determined maximum reading. Such a precaution demanded a great amount of additional time and patience;

nevertheless it successfully eliminated the disturbance, which was very detrimental to the accuracy of the observed readings of the needle. All the measurements herein given were taken by the above method. The readings thus taken are very small, the highest not exceeding three small divisions of the Mille-Ampère meter scale; but they are otherwise perfectly regular, showing a distinct increase and decrease with change of position of the coherer from the reflector. Readings can be taken with a fair degree of rapidity, when all conditions are favorable; as many as forty having been taken in three hours. Measurements were begun as near the reflector as possible and continued towards the oscillator. The first zero reading was located at 1·1500 m. from the reflector and the first maximum at 2·6290 m. from the reflector. The second zero was found to be at 4·1075 m. and the second maximum at 5·5863 m., while the third zero was at 7·0650 m. from the reflector. We, therefore, have a distance of 1·4790 m. between the first anti-node and node, 1·4785 m. between the first node and second anti-node, 1·4788 m. between the second anti-node and second node and 1·4787 m. between the second node and third anti-node. This gives us a distance of 2·9575 m. between the first and second anti-nodes and also 2·9575 m. between the second and third anti-nodes; that is to say, the half wave-length is 2·9575 m., or the wave-length is 5·915 m. Accordingly there should be a node at ·3290 m. back of the reflector. No results are here recorded of the observations made nearer to the oscillator than a full wave-length. For as one approaches the oscillator in this distance, though the readings show increases and decreases yet no actual zero reading was located. Moreover in this space, the phenomenon above described was very strongly active and difficult to overcome. The measurements below tabulated were all taken in the space at least a wave length distant from the oscillator. The following are the results of nearly 500 observations. The first column gives the distances of the coherer from the reflector, columns two and three give the readings on the Mille-Ampère meter scale for the first maximum reading and the increased reading, while column three shows the increase in the readings due to the passage of the electric waves. Five measurements at least were taken at each point of observation. Owing to the space all the readings occupy, only a few of them are here given. The general nature of the rest of the readings can be seen from the curve (p. 12).

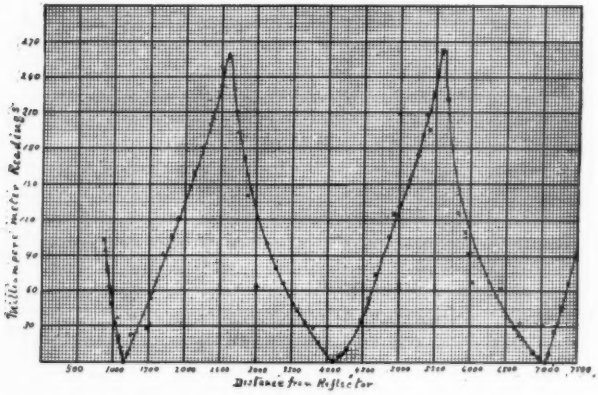
Distances in ms. from the reflector.	First maximum reading.	Increased maximum reading.	The increase due to the electric waves.	
0·9100	8·050	8·125	0·075	
	7·800	7·900	0.100	
	7·900	8·010	0·110	
	7·550	7·650	0·100	
	8·000	8·100	0·100	mean
	8·575	8·650	0·075	0·1035
	7·700	7 825	0·125	
	8·100	8·225	0·125	
	7·950	8·050	0·100	
	7·900	8·025	0·125	
1·1425	5·750	5·750	0·000	
	5·750	5·750	0·000	mean
	5·600	5·605	0·005	0·0030
	5 450	5·455	0·005	
	5·775	5·780	0·005	
1·1500	7·725	7·725	0·000	
	7·400	7·400	0 000	mean (of
First zero or	8·450	8·450	0·000	20 results)
first anti-node	7·450	7·450	0·000	0·0000
	7·850	7·850	0·000	
1·1705	7·160	7·166	0·006	
	7·450	7·450	0·000	mean
	8·565	8·570	0·005	0·0040
	8·500	8·509	0·009	
	8 400	8·400	0·000	
1·2500	8·050	8·060	0·010	mean (of
	8 400	8·410	0·010	5 results)
	8·900	8·910	0·010	0·0100
1·2710	7·700	7·715	0·015	mean (of
	8·065	8·075	0 010	5 results)
				0·0130
2·2500			0·1760	
2·3450			0 1900	
2·4000	The readings are left out,		0·2000	means of
2·4150	only the means of 5 results given		0·2050	5 results
2·4745			0 2270	each
2·5000			0·2350	
2·6290	8·300	8·566	0·266	
	7·400	7·630	0·230	mean (of
First	7·550	7·800	0·250	12 results)
node	7·560	7·775	0·275	0·2600
	7·200	7·475	0·275	
2·6800			0·2250	
2·7500			0·1930	
2·7960			0·1800	
2·8860			0·1530	
3·0000			0 1350	
3·0660			0·1200	
3·1960	The readings are left out,		0·1000	means of
3·2950	only the means of 5 results are given		0·0780	5 results
3·4000			0·0660	each
3·5110			0·0510	
3·6040			0·0440	
3·7040			0·0340	
3·8050			0·0260	
3·9270			0 0120	

Distances in ms. from the reflector.	First maximum reading.	Increased maximum reading.	The increase due to the electric waves.	
4·1075	8·400	8·400	0·000	
	8·750	8·750	0·000	
Second zero or second anti-node	8·400	8·400	0·000	mean (of 15 results) 0·0000
	8·500	8.500	0·000	
	7·600	7·600	0·000	
	7·400	7·400	0·000	
4·1876			0·0050	
4·2876			0·0120	
4·2880			0·0130	
4·2940			0·0140	
4·3350			0·0150	
4·5056			0·0350	
4·5600			0·0540	
4·6650	The readings are left out, only the means of 5 results are given		0·0740	means of 5 results each
4·7250			0·0750	
4·8640			0·1060	
4·9150			0·1140	
5·0000			0·1300	
5·1700			0·1520	
5·2830			0·1720	
5·3285			0·1780	
5·4500			0·1960	
5·5863	8 000	8·233	0·233	
	7·900	8·160	0·260	mean (of 20 results) 0·2620
Second node	8·000	8·280	0·280	
	8·000	8·285	0.285	
	7·400	7.650	0.250	
5·6215			0·2460	
5·6925			0·2260	
5·8150			0·1250	
6·7000	The readings are left out, only the means of 5 results are given		0·0220	means of 5 results each
6·7135			0·0200	
6·7140			0·0170	
6·8850			0·0100	
7·0330			0·0040	
7·0650	7·300	7·300	0·000	
	7·400	7·400	0·000	
	8·850	8 850	0·000	mean (of 25 results) 0·0000
Third zero or third anti-node	8·000	8·000	0·000	
	8·950	8 950	0·000	
	7·000	7·000	0·000	
7·0660			0·0010	
7·1450			0·0060	
7·1775	The readings are left out, only the means of 5 results are given		0·0250	means of 5 results each
7·2945			0·0450	
7·5000			0·0800	

The means of each of these sets of five readings are taken and plotted as a curve, the coördinates of whose points are the distances of the coherer from the reflector and these mean values. The resulting curve is given in fig. 1.

The velocity of the electric waves was determined from the formula $\lambda = VT = 2\pi V\sqrt{LC}$ where λ is the wave-length, L the self-induction, C the capacity, V the velocity and T the time of oscillation of the secondary spark. T was found by the photographic process. The sparks directly given by the oscillator used in the original experiment could not be photographed. They were too small and, moreover, their light was not actinic enough. Sparks given by similar capacity and self-induction but of larger dimensions and cadmium points in place of the platinum globules were photographed. The self-induction here used consisted of two parallel

1.



copper wires of the same diameter as were employed in the original experiment, 5 cm. apart and 1051·1 cm. in length. The capacity was the same glass plate with the tin foil sheets four times as large. The time of oscillation of the sparks thus produced was found to be $4{\cdot}12382 \times 10^{-7} = T'$ seconds. It was then assumed, that the formula must still hold good if we cut down the self-induction and capacity, still keeping the copper wires 5 cm. apart. That is to say, if we make our C one-fourth and our L $\frac{1}{100}$th of the L used in the photographic process the time of oscillation of our spark will be $\frac{1}{20}$th of that of the spark photographed. In the original experiment the area of the tin foil was just one-fourth of that on the condenser which formed the capacity for the spark photographed, whereas the length of copper wire was 9·62 cms, being $\frac{9{\cdot}62}{1051{\cdot}1}$ of what was used in the photographic process. Accordingly

the time oscillation of our spark would be $1{\cdot}976\times10^{-8}$ secs. This is then the value of T. We have already found λ, the wave-length, to be 591·5 cms. And since $\lambda = VT \therefore V$ the velocity of the electric wave $= \frac{\lambda}{T} = \frac{591{\cdot}5}{1{\cdot}976\times10^{-8}} = 2{\cdot}998\times10^{10}$ centimeters per second or about 186,365 miles per second.

Professor Trowbridge and Dr. Duane in 1895 found the velocity of electric waves along wires to be $2{\cdot}996\times10^{10}$ cms, though the mean of seven of their results gave the velocity to be $3{\cdot}0024\times10^{10}$ cms. per second. To make sure the coherer and oscillator were in tune with each other, the capacity of the oscillator was altered by doubling the area of the tin foil sheets on the glass plate. Sparking at the oscillator was again begun and readings taken whereby it was seen the positions of the original nodal and anti-nodal points were changed. The same thing took place upon altering the self-induction. Also separately the self-induction and capacity of the coherer were altered, with a similar change in the position of the original nodal and anti-nodal points. When the wave-length had been determined it seemed desirable to test the truth of the theory of Poincaré and Bjerknes. It is a known fact in the photography of electric oscillation, that it is possible to damp out all the oscillations except the fundamental by replacing part of the self-induction by a self-induction having a higher resistance. As, for example, interchanging a length of copper wire by the same length of graphite. Accordingly a cylinder of graphite 5 cms. long was ground down till it had the same diameter of the copper wire it was to replace. The ends of this rod of graphite were next electroplated with copper. Five cms. of one of the copper wires forming the self-induction of the coherer were cut out and replaced by soldering in the prepared graphite. The coherer and oscillator circuits had now the same capacity and self-induction as before, only the resistance of the self-induction of the coherer circuit had been increased. The resistance of the graphite was 12 ohms. Work was now undertaken under these new conditions, with the result that the fifty observations thus made were identical with those taken under the original conditions. The following table gives the measurement taken when the graphite was in the circuit.

Distance in cms. from the reflector.	First maximum reading.	Increased maximum reading.	The increase due to the electric waves.	
1·1500	8·100	8·100	0·000	
	8·550	8·550	0·000	
	8·450	8·450	0·000	mean 0·0000
	6·450	6·450	0·000	
	8·250	8·250	0·000	
2·6290	8·600	8·825	0·225	
	8·000	8·250	0·250	
	7·600	7·850	0·250	mean 0·2600
	7·800	8·100	0.309	
	8·550	8·825	0 275	
2·7960	8·150	8·325	0·175	
	7·400	7·565	0·165	
	7·450	7·650	0·200	mean 0·1800
	6·475	6·650	0·175	
	8·000	8·185	0·185	
3·1960	7·800	7·900	0·100	
	7·750	7·850	0·100	
	7·250	7·400	0·125	mean 0·1000
	8·425	8·500	0·075	
	8·400	8·500	0·100	
4·1075	8·750	8·750	0·000	
	8·350	8·350	0·000	
	7·100	7·100	0·000	mean 0·0000
	8·300	8·300	0·000	
	8·400	8·400	0·000	
3·4000	8·800	8·850	0·050	
	8·425	8·500	0 075	
	8·400	8·466	0·066	mean 0·0660
	8·500	8·575	0·075	
	8·100	8·165	0·065	
4·5056	8·150	8·175	0·025	
	7·750	7·800	0·050	
	8·350	8·400	0·050	mean
	8·575	8·600	0·025	0·0375
	8·300	8·350?	0·050?	
	7·835	7·860	0·025	
5·5863	8·400	8·625	0·225	
	8·450	8·700	0·250	
	8·150	8·450	0·300	mean 0·2620
	8·500	8·750	0·250	
	8·450	8·735	0·285	
6·6670	8·250	8·300	0·050	
	8·400	8·425	0·025	
	8·500	8·525	0·025	mean 0·0350
	8·100	8·150	0·050	
	8·550	8·575	0·025	
7·0650	8·950	8·950	0·000	
	8·800	8·800	0·000	
	8·650	8·650	0·000	
	8·600	8·600	0·000	
	8·800	8·800	0·000	mean
	7·350	7·350	0·000	0·0000
	7·450	7·450	0·000	
	7·600	7·600	0·000	
	7·845	7·845	0·000	
	8·000	8·000	0·000	

This latter experiment shows that the wave-length we have measured was that of the fundamental wave. And, moreover, that by the use of this particular coherer or the electro-bolometer, the balancing of the self-inductions and capacities and by our method of operating the oscillator, all the electric waves in the number of different waves proceeding from the Ruhmkorff coil, except the fundamental, had been completely damped. If such had not been the case, it is very evident the measurement so taken would not have been identical with those first observed.

The experiment was pushed further. The new self-induction (graphite) of the coherer circuit being retained, the capacity of the oscillator circuit was made double of what it was in the original case and, therefore, double of that now in the coherer circuit. At those points where the original readings indicated nodes and anti-nodes the readings were now changed. The following table shows some of the changes.

	The new self-induction in the coherer circuit and the original capacity in the oscillator circuit.	The new self-induction in the coherer circuit and the capacity in the oscillator circuit, doubled.
Distance in ms. of the coherer from the reflector.	Difference between the maximum and increased maximum readings of the m-a-m.	Difference between the maximum and increased maximum readings of the m-a-m.
1·1500	0·000	0·075
2·6288	0 260	0·275
4·1075	0·000	0·150
5·5863	0·262	0 250
7·0650	0·000	0 081
	(average of 5 readings)	(average of 5 readings)

Similar changes took place at other points.

Next the capacity of the coherer circuit was altered and as a consequence, at those points where the original readings were taken, the readings now were different. Finally the capacity (i. e. the tinfoil plates) of the coherer circuit was left out entirely and so also was the self-induction, for at this stage of the experiment the graphite broke. The readings were now of all sorts, the needle moving very capriciously, whenever the sparking began or continued at the oscillator. No regular increase and decrease in the readings could be determined, as the coherer was moved farther and farther from the reflector. At one time the needle would be deflected four or five whole divisions of the Mille-Ampère meter scale while in the next second, at the same place, there would be only a displacement of the needle of ·2 or ·3 of a division in the forward direction or else a deflection in the opposite direction, and even at times the needle trembled as if acted upon by almost equally opposing influences. These irregular motions of the needle made a great contrast with the regular motions when the coherer and

oscillator were in tune. This experiment confirms the truth of the damping theory of Poincaré and Bjerknes.

Sarasin and de la Rive's theory of a multiplicity of waves of different amplitudes originating at the same oscillator was substantiated by the erratic readings obtained when the coherer proper alone was employed. In fact the truth of their theory was readily seen when the ordinary metal filings coherer or Branly tube was used, since the irregularity of the readings was evidently such as would be produced by quickly succeeding waves of different kinds acting upon the tube. The point which might be the position of a node due to one wave would be the anti-node or at least not always the node due to the next following wave.

I desire here to express my gratitude to Professor Trowbridge for his valuable suggestions, his assistance and his very great kindness in placing at my disposal the resources of the Physical Laboratory in order to have this experiment carried to a successful completion.

Jefferson Physical Laboratory, Harvard University,
Cambridge, Mass., April, 1899.

Art. II.—*A Spiral Fulgurite from Wisconsin;* by William H. Hobbs.

There has recently been presented to the geological collection of the University of Wisconsin a lightning tube or fulgurite which has considerable interest because of its shape—a perfect dextro-rotary helix. The specimen is the gift of Mr. G. H. Kruschke, town clerk of the town of Cutler, Wisconsin, who has furnished me with the data for the following description of the manner of its discovery.

The fulgurite was discovered in October, 1897, by Frank de Lap, Mr. Kruschke's son-in-law, while digging a cellar on the southeast quarter of the northeast quarter of Sec. 20, T. 18, R. 2 E., Town of Cutler, Juneau County, Wisconsin. It was imbedded in a sand knoll about ten feet high, at a distance of five feet below the surface. A house has since been built upon the spot.

A sample of the sand in which the tube was found has been kindly furnished by Mr. Kruschke, and proves on examination to be a fairly clean sand, of a light brown color, largely composed of translucent quartz grains which average about $\frac{1}{64}$th of an inch in diameter. The coloring matter appears to be ferric oxide. The tube itself is about as thick as a man's thumb, and over five inches long. When found it was about three inches longer, but Mr. Kruschke reports that a piece was accidentally broken off and lost. Examination of the broken end shows that the fulgurite is composed of a dull gray slaggy mass, filled with larger and smaller cavities exactly like those observed in porous natural slags. There are a few dark specks surrounded by stains of iron oxide. Somewhat excentrically located in this end section is a cavity of irregular cross-section which appears to extend into the fulgurite as a more or less continuous tube, but is so bent and locally contracted that it is impossible to follow it for any distance. Its average diameter is about $\frac{3}{16}$th of an inch, but it is partly filled by blister-like eruptions which protrude from its walls. One of these blisters which is broken open has walls as thin as paper.

The other end of the fulgurite has not been broken in any way but forms four irregular horn-like projections (*a-a-a* in the left of fig. 1). The channel (it cannot be asserted that this is continuous with the one observed at the other end) emerges at one side of the fulgurite (*a*, in right hand portion of fig. 1) with only a thin wall less than a millimeter in thickness on the outer side.

The surface of the fulgurite is very irregular, being traversed by corrugations whose greatest extension is in the direction of the longer axis of the fulgurite, though they exhibit some tendency to wrap themselves around it in a dextro-rotary manner. These corrugations appear to be, for the most part, thin-walled tubes (*b*, at the left in fig. 1) which are not now con-

1.

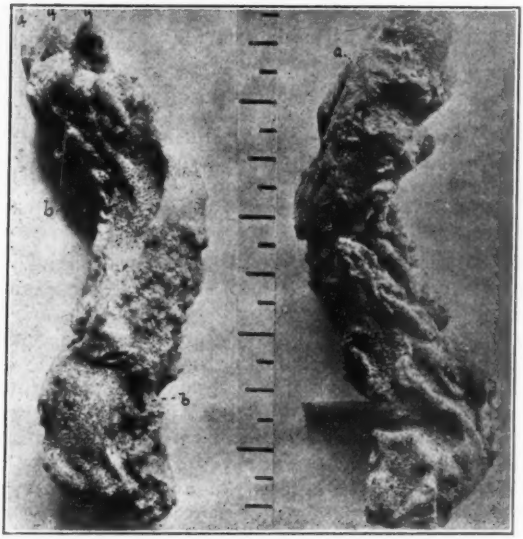


FIG. 1. Spiral fulgurite from Cutler, Wisconsin, showing opposite sides. The units in the scale are inches. *a*, *a*, *a*, in the figure at the left, horn-like protuberances terminating the fulgurite. *b* of the same portion of the figure, corrugations broken open and exhibiting thin-walled tubes. *a* in figure at the right, point of emergence of main channel (hidden in the view).

tinuous passages, but are so distorted and contracted locally as to suggest that they have suffered collapse since their formation.

Over the entire outer surface of the fulgurite are grains of sand which show varying degrees of former fusion. Those which have been completely fused are opaque and white, and are firmly cemented to the glass of the tube. The others adhere less firmly and where distributed abundantly appear brown, as in the sample of loose sand from the locality. The photographs shown in fig. 1 exhibit opposite sides of the fulgurite and indicate, as well as any photographs are likely to do, its perfectly helical form. The only fulgurite known to me

which shows any approach to this shape is that from Waterville, Maine, described by Bayley,* which has marked corrugations that wind about the axis of the fulgurite in the form of a dextro-rotary helix.

The fact that the Waterville and Cutler fulgurites show each a spiral twist of the same type is sufficient evidence that the

2.

FIG. 2. Artificial fulgurites made by Prof. Wood. The units in the scale are inches. *a* is a tube with branch-like protuberance at the side. *b* is a tube of nearly symmetrical cross-section. *c* is a tube with marked corrugation extending along one side. *d* exhibits the cross-section of a large tube.

structure is not an accidental one, but one to be explained by the conditions of the lightning discharge, which doubtless followed a spiral course through the sand. Professor R. W. Wood, of the Physical Department of the University of Wisconsin, has suggested to me that this may be explained in some way by the influence of the earth's magnetic field upon the discharge. There is at least a possibility that there may be some analogy between the experiments of Hittorf† with electric

* A Fulgurite from Waterville, Maine, by W. S. Bayley, this Journal (3), 1892, xliii, p. 327.

† J. J. Thomson, Recent Researches in Electricity and Magnetism. Oxford, 1893, p. 134.

discharges in a magnetic field, and the lightning discharge. Hittorf found that in the case of negative discharge in a direction nearly parallel to a line of force that the spark takes the form of a dextro-rotary spiral and wraps itself about the line of force. It hardly seems possible that the earth's field would be sufficiently strong to effect such a change in the course of the lightning, and, moreover, the return discharge would be of an opposite character, and should produce a spiral of the opposite kind unless the initial discharge controls the form of the sand tube. The above is, therefore, offered only as a suggestion and not in any sense as an adequate explanation.

I do not remember to have seen any description of artificial fulgurites. Professor Wood, on being shown the Cutler fulgurite, expressed the belief that he could make some of the ordinary kind. Within a half hour he had produced the tubes which are shown in fig. 2, by immersing carbon electrodes in a bath of sand and passing the current from an ordinary arc circuit through them. In *a* of the figure is seen a fulgurite having a hollow protuberance on one side—really a branch of the tube; *b* is a tube of fairly symmetrical cross section; the tube *c* has a marked corrugation extending along one side, and shows perhaps a slight trace of spiral curving; while *d* (shown in cross section) indicates how large fulgurites may be made by this simple method. I am indebted to Professor Wood for permission to publish a photograph of these artificial fulgurites.

University of Wisconsin.

ART. III.—*On the Chemical Composition of Parisite and a new occurrence of it in Ravalli Co., Montana;* by S. L. PENFIELD and C. H. WARREN.

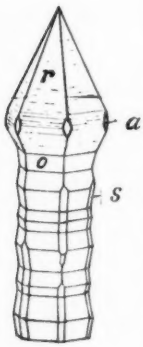
RECENTLY Mr. Lazard Cahn of New York sent to the Mineralogical Laboratory of the Sheffield Scientific School for identification, several specimens from Montana, showing crystals of an unusual appearance. These proved to be the rare mineral parisite, hitherto observed only in small amount at the original locality, the emerald mines of the Muso Valley, United States of Columbia; sparingly at Ober Arö, Langesundfiord, Norway;* and quite recently the mineral has been found at Narsásuk in Southern Greenland. A brief note on its occurrence at the latter locality was made by Gust. Flink in the report of a trip made there during the summer of 1897.

Not only does a new occurrence of parisite and the peculiar habit of the crystals deserve notice, but the chemical composition of the mineral has never been determined with certainty, and, therefore, analyses have been made for the purpose of determining this important character. It is with pleasure that we express to Mr. Cahn our thanks for a generous supply of the material from Montana for analysis.

The parisite crystals from Montana are supposed to have come from near Pyrites, Ravalli County, and occur in a fine-grained, loosely coherent, white material, which can be readily crushed to a powder with the finger nail. The matrix consists essentially of silica, alumina, calcium and a little alkali, and has the appearance of a decomposed rhyolite or trachyte, but its exact nature has not been more definitely determined. Through this white material crystals of pyrite and parisite are scattered, generally isolated, but at times the parisite has grown over and partly or completely surrounded the pyrite crystals. The pyrite is crystallized in pyritohedrons modified by small faces of the cube and octahedron, and the crystals vary in size from microscopic up to 3^{mm} in diameter. The average size of the parisite crystals is about 1^{mm} in diameter by 10^{mm} in length. They are quite numerous, so that from four to ten individuals may be seen on a surface of ten square centimeters of the matrix. The habit which they generally present is that of a horizontally striated hexagonal shaft, made up of steep pyramids in oscillatory combination and terminated at the ends by distinct, somewhat enlarged pyramids. The accompanying figure, which represents a portion of the shaft and one termination, gives a fair idea of the development of the crystals. The faces which are most prominent in forming the shaft are those of the pyramid o (20$\bar{2}$1) in oscillatory combination. Measurements over the reëntrant and salient angles

* Brögger, Zeitschr. Kr., xvi, 650, 1890.

could be made with the reflecting goniometer and are given in an accompanying table. Some of the edges of the pyramid o are truncated by a pyramid of the second order s ($11\bar{2}1$), also in oscillatory combination, but, as shown in the figure, this form generally is not continuous throughout the whole length of the shaft nor is it present on all the edges. The pyramid which finally terminates the crystals is r ($20\bar{2}3$). This is generally quite distinct, although its middle edges are somewhat rounded by a system of fine horizontal striations. The prism of the second order a ($11\bar{2}0$), represented in the figure, is always small and frequently wanting. The prism of the first order, m ($10\bar{1}0$), was not observed as a distinct face, although the oscillatory combination of the upper and lower pyramidal faces often gave rise to striated, rounded, surfaces which approximate in position to the faces of this prism. Occasionally the shafts taper to a point without the enlarged pyramid. Of the forms observed, a ($11\bar{2}0$), r ($20\bar{2}3$), o ($20\bar{2}1$), s ($11\bar{2}1$) and m? ($10\bar{1}0$), the prism a is new. The angles which were measured are given below, together with the values calculated from the vertical axis established by Des Cloizeaux,* $c = 3{\cdot}2891$.



	Measured.	Calculated.
$a \wedge a = 11\bar{2}0 \wedge \bar{1}2\bar{1}0 =$	59° 54′	60° 00′
$r \wedge r = 20\bar{2}3 \wedge 02\bar{2}3 =$	55 25	55 25½
$r \wedge r = 20\bar{2}3 \wedge \bar{2}023 =$	137 22	136 54
$s \wedge s = 11\bar{2}1 \wedge 11\bar{2}\bar{1} =$	17 23	17 18
$o \wedge o = 20\bar{2}1 \wedge 20\bar{2}\bar{1} =$	13 10	14 00

For the chemical analysis the best material that could be obtained was secured by picking out the crystals from the matrix by hand, and rubbing them between the fingers to remove any loosely adhering material. The crystals enclosed, as has been said, a little pyrite and were not very firm, consequently some siliceous material was deposited in the cracks. These impurities amount to about six per cent. The material was of a nearly uniform yellowish brown color.

The method of analysis was as follows: Carbon dioxide was obtained by dissolving the mineral in hydrochloric acid and collecting the gas evolved in weighed potash bulbs. For fluorine, another portion of material was fused with sodium carbonate and a weighed amount of silica, and the fluorine separated and estimated by the Berzelius method as modified by Penfield and Minor.† The earths were separated from calcium by repeated precipitations with ammonia, and they were then converted into oxalates, ignited, and weighed as

*Min., ii, p. 162, 1874.

†This Journal, III, xlvii, p. 387, 1894.

oxides. The amount of cerium oxide, Ce_2O_3, was estimated by decomposing the ignited oxides (CeO_2, La_2O_3 and Di_2O_3) with sulphuric acid, to which some oxalic acid was added, and weighing the carbon dioxide liberated by the higher oxide of cerium, according to the equation, $2CeO_2+H_2C_2O_4=Ce_2O_3+2CO_2+H_2O$. The joint molecular weight of the cerium, lanthanum, and didymium oxides $(Ce, La, Di)_2O_3$ was estimated by converting a weighed quantity of the oxides into sulphates and was found to be 328·2. The results of the analyses are given beyond.

As the considerable amount of impurities in the Montana parisite rendered the calculation of the formula somewhat uncertain, an analysis of the mineral from Muso Valley was also made. Exceptionally pure material for this analysis was obtained from a fragment of a large crystal in the Brush collection. In this analysis it was found that the full amount of fluorine was not obtained by a single fusion with sodium carbonate and silica, and soaking out with water. By saving the residues and fusing them a second time with sodium carbonate and a slight addition of silica, about 0·5 per cent of fluorine was obtained. This precaution was not taken in the analysis of the Montana mineral and consequently the ratio of the fluorine in that analysis is a little low. The joint molecular weight of the cerium, lanthanum and didymium oxides was found to be 328·4. The results of the analyses are given below, together with the analysis by Damour and Deville* of the parisite from Muso.

	I. Warren. Montana.	Ratio.	II. Warren. Muso.	Ratio.	III. Damour and Deville. Muso.	Ratio.
Specific gravity,	4·128		4·302		4·358	
CO_2	22·93	·521	24·22	·550	23·48	·533
F	5·90	·310	6·82	·359	5·55	·292
Ce_2O_3	26·14	·166	30·67	·183	44·21	·187
$(La, Di)_2O_3$	28·46		29·74		18·00	
CaO	10·98	·196	10·70	·191	10·10	·180
Fe_2O_3 (pyrite ?)	·80		·20		101·34	
Na_2O	·69		·20		0 = 2F = 2·34	
K_2O	·19		.10		99·00	
H_2O	·26		102·65			
Gangue by difference	6·13		0 = 2F = 2·87			
	102·48		99·78			
0 = 2F	2·48					
	100·00					

* C. R., lix, p. 270, 1864.

The ratios derived from the foregoing analyses are as follows:

	CO_2 :	F :	$(Ce, La, Di)_2O_3$:	CaO	
I.	·521 :	·310 :	·166 :	·196 = 3·00 :	1·79 : 0·96 : 1·13
II.	·550 :	·359 :	·183 :	·191 = 3·00 :	1·96 : 1·01 : 1·04
III.	·533 :	·292 :	·187 :	·180 = 3·00 :	1·65 : 1·05 : 1·01

The new analysis of the exceptionally pure material from Muso Valley gives a ratio approximating very close to 3 : 2 : 1 : 1. The material from Montana is not so pure, consequently the ratio is less satisfactory. The fluorine in the mineral doubtless caused some of the gangue material to go into solution, thus causing the calcium to be a little high; while the fluorine is evidently low, because, as previously stated, the precaution was not taken to repeat the fusion with sodium carbonate and silica in estimating that constituent. The ratio obtained by Damour and Deville agrees with those obtained from the new analyses except as regards fluorine. It is believed, however, that their method of estimating fluorine is open to criticism, since they made no direct determination of this element but, assuming that on dissolving the mineral in very dilute hydrochloric acid the fluorine separated out completely as the fluorides of calcium and cerium, they ascertained the weight of these fluorides, and considered fluorine as equal to the difference between this weight and that of the calcium and cerium derived from an analysis of the insoluble residue.

Excepting the defects in the analyses, evidently due to failures in estimating fluorine correctly, the ratios derived from the three analyses indicate conclusively that CO_2, F, $(Ce, La, Di)_2O_3$ and CaO are united in the proportion of 3 : 2 : 1 : 1. Representing the trivalent metals of the cerium group collectively by R, it is probable that fluorine is directly united with them to form a bivalent radical (RF), and that parisite is a double carbonate, $2(RF)CO_3 + CaCO_3$, or $(RF)_2Ca(CO_3)_3$.

As far as the proportions of the different constituents is concerned, either of the foregoing expressions is equivalent to the formula proposed by Groth† $(CaF)'(CeF)''Ce(CO_3)_3$. Groth based his formula upon the single analysis of Damour and Deville, previously cited, and was correct in assuming that the deficiency in fluorine was due to a failure to estimate that constituent correctly. It seems to us more reasonable to consider the fluorine as playing a single role, united with the Ce, La, and Di metals to form a bivalent radical (RF), than to adopt the formula of Groth where fluorine plays a double role, united with calcium to form a univalent radical (CaF) and with cerium to form a bivalent radical (CeF).

* Tabellarische Uebersicht der Mineralien, 1898, p. 61.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, April, 1899.

ART. IV.—*The Estimation of Iron in the Ferric State by Reduction with Sodium Thiosulphate and Titration with Iodine;* by JOHN T. NORTON, JR.

[Contributions from the Kent Chemical Laboratory of Yale University—LXXXIII.]

THE action of sodium thiosulphate on ferric iron has long been known and depends upon the following reaction :

$$2FeCl_3 + 2Na_2S_2O_3 = 2FeCl_2 + Na_2S_4O_6 + 2NaCl.$$

As early as 1859 Sherer* proposed a method for the estimation of ferric iron depending on the above reaction. Sherer's method of procedure was to act upon a solution of ferric chloride with sodium thiosulphate until the purple color produced by the interaction of these two salts just vanished. Mohr's† experimental tests of this process were not successful. A year or two later Kremer and Landolt,‡ after a careful investigation of Sherer's process, recommended it with the modification that any free hydrochloric acid present should be neutralized by sodium acetate until the solution assumed a red color, just enough hydrochloric acid added to destroy this red color, and sodium thiosulphate run into the solution in slight excess. When the liquid became perfectly colorless and gave no reaction for ferric iron with potassium sulphocyanide, the excess of sodium thiosulphate was titrated back with iodine and starch. The authors also state that the ferric iron should not be present in concentrated solution. Very good results were claimed for this process, but it apparently gained but slight recognition.

Oudemanns,§ who was the next to study the action of ferric iron and sodium thiosulphate, claimed that the addition of a small quantity of cupric salt to the iron solution hastened the reducing action of the sodium thiosulphate. Mohr,‖ however, condemned this method also as unreliable, both because the sodium thiosulphate acted upon the copper as well as the iron and also because the potassium sulphocyanide, added as an indicator of the completeness of the reduction, produced a precipitate of cupric sulphocyanide which interfered with the reaction. In a second paper Oudemanns¶ reiterated his former statement as to the accuracy of his method but advised the use of a smaller quantity of the cupric salt. An improvement on Oudemanns' process was proposed by Haswell,** who mixed

* Gelehrte Anzeigen der könig. Bayrisch. Acad. vom Aug. 31, 1859.
† Anal. d. Chem. u. Pharm., cxiii, 260.
‡ Zeitschr. f. Anal. Chem., 1, 214.
§ Zeitschr. f. Anal. Chem., vi, 129.
‖ Titrirmethode
¶ Zeitschr. f. Anal. Chem., ix, 362.
** Repertorium der Analytischen Chem., i, 179.

the moderately acid solution of ferric chloride in the presence of a cupric salt with a few drops of sodium salicylate and then reduced with sodium thiosulphate previously standardized upon a known quantity of iron by the same process and estimated the excess by potassium dichromate. Bruel* modified this process by operating without the copper solution, relying merely on the discharge of the violet color in a boiling solution by sodium thiosulphate standardized on a ferric solution of known strength.

Although considerable work has been done on the reaction between ferric iron and sodium thiosulphate, no process depending upon this reaction has obtained acceptance. In view, therefore, of previous work on the action of hydrochloric acid upon sodium thiosulphate† and with the idea that a careful control of the dilution and quantity of acid present might greatly better the accuracy of the method, it has seemed to me to be desirable to study this process again in detail.

The ferric oxide employed in the experiments was prepared with great care by the ignition of ferrous oxalate obtained by acting with oxalic acid on pure ammonium ferrous sulphate. To ascertain, however, if this oxide contained any impurity, about 0·5 of a grm. was put into a porcelain boat and submitted to the action of a current of hydrochloric acid gas and chlorine at a temperature of about 280° C. (according to a process recently described from this laboratory‡) until all the ferric salt is volatilized in the form of ferric chloride. A residue of 0·0010 grm. for every 0·5 of a grm. of the oxide was found, and this correction, small for the amounts generally used, has been applied in the following determinations. The sodium thiosulphate used was taken in nearly $\frac{n}{10}$ solution and was standardized against an approximately decinormal solution of iodine which had been determined by comparison with decinormal arsenious acid made from carefully resublimed arsenious oxide.

In those experiments which deal with amounts of ferric oxide not exceeding 0·2 of a grm., measured portions of a solution of ferric chloride made of known strength by dissolving about 2 grms. of the pure carefully weighed ferric oxide in 20^{cm^3} of strong hydrochloric acid and diluting to one liter, were drawn from a burette. In the case of the larger quantities of ferric oxide the salt was weighed out, dissolved in hydrochloric acid and brought to the required dilution. The ferric chloride, either drawn from the burette or prepared directly from the weighed oxide, was diluted with water, a drop of potassium

* Compt. Rendus, xcvii, 954.

† This Journal, vol. vii, 287.

‡ Gooch and Havens, this Journal,

sulphocyanide added to serve as an indicator and an excess of sodium thiosulphate was run in until, after standing for a few minutes, the solution became perfectly colorless, and the excess of sodium thiosulphate was then titrated back with decinormal iodine after the addition of starch.

Several sources of error are, plainly, possible in the process: incompleteness in the reduction of the ferric salt; decomposition of the thiosulphate by the acid, resulting in the subsequent over-run of iodine; the possible tendency of the ferric salt under concentration to oxidize the thiosulphate to the condition of the sulphate rather than to that of the tetrathionate; and finally the oxidizing action of the air, which may tend to keep up progressive oxidation of the iron salt and excessive expenditures of thiosulphate. The first three sources of difficulty tend to produce errors of deficiency; the fourth an error of excess.

The first step in the experimental study of the process was to determine the effect of varying dilution upon the estimation of a given quantity of iron reduced by sodium thiosulphate, taken in practically uniform excess above the amount theoretically required, in the presence of 1$^{cm^3}$ of hydrochloric acid.

TABLE I.

	Fe_2O_3 taken. grms.	Fe_2O_3 corrected. grms.	Dilution. cm^3.	HCl. cm^3	$Na_2S_2O_3$ in excess. cm^3.	Fe_2O_3 found. grms.	Error. grms.
1.	·1000	·0998	100	1	18·08	·0957	·0041 —
2.	·1000	·0998	200	1	20	·0966	·0032 —
3.	·1000	·0998	300	1	17·56	·0995	·0003 —
4.	·1000	·0998	400	1	17·16	·0998	·0000
5.	·1000	·0998	600	1	17·76	·0996	·0002 —
6.	·1000	·0998	800	1	17·65	·0993	·0005 —
7.	·1000	·0998	1000	1	18·02	·0988	·0010 —
8.	·1000	·0998	1200	1	17·95	·0977	·0021 —
9.	·1000	·0998	1400	1	17·99	·0965	·0033 —
10.	.1000	·0998	1600	1	18·01	·0947	·0051 —
11.	·2001	·1997	400	2	27·05	·2029	·0032 +
12.	·2001	·1997	800	2	15·95	·1998	·0001 +
13.	·4998	·4988	1000	2	22·36	·5104	·0126 +
14.	·5051	·5041	1800	4	15·27	·5026	·0017 —
15.	·4002	·3994	1500	4	27·29	·3996	·0002 +
16.	·7502	·7487	1000	1	9·73	·7572	·0085 +
17.	·7029	·7015	2000	4	12·67	·7004	·0011 —

This table shows plainly that with quantities of ferric oxide present up to 0·1 grm. the dilution can vary from 400$^{cm^3}$ to 1000$^{cm^3}$ for each cm^3 of strong hydrochloric acid and still give excellent results. At a dilution greater than 1000$^{cm^3}$ the action of the thiosulphate is evidently incomplete, and at a

smaller dilution than 400$^{cm^3}$ the decomposing action of the acid on the thiosulphate becomes noticeable. When larger quantities of iron oxide are dealt with, it appears that the dilution ought to be increased proportionally with the quantity of ferric oxide present as well as with that of the acid. This is illustrated in experiments 9–15 of the table. On this account it seems necessary, assuming that the quantity of acid present is always kept within the maximum strength mentioned, 1$^{cm^3}$ to 400$^{cm^3}$, to regulate the dilution from the approximate quantity of the iron so that not less than 400$^{cm^3}$ of water shall be used to every 0·1 grm. of iron oxide present. Under properly regulated conditions of dilution as regards acid and the iron salt, the reduction is completed in from five to ten minutes.

Great excesses of acid, however, contrary to the statement of Kremer,* retard the reduction greatly, and, in spite of the tendency of the thiosulphate to decomposition and the production of errors of deficiency under such circumstances, plus errors due to partial oxidation come to light. This fact appears in the following table, which records the results of processes lasting many hours.

TABLE II.

	Fe_2O_3 taken. grms.	Fe_2O_3 corrected. grms.	Dilution. cm^3.	HCl. cm^3.	$Na_2S_2O_3$ in excess. cm^3.	Fe_2O_3 found. grms.	Error. grms.
18.	·5012	·5002	1700	10	25·99	5308	·0306+
19.	·7512	·7497	1200	15	57·8	7685	·0188+
20.	·7520	·7505	2000	15	56·4	7983	·0478+
21.	·7520	·7505	1700	15	27·2	7627	·0122+

As to the temperature at which the reduction should be made, my experience, contrary to that of Kremer, goes to show that no elevation above atmospheric conditions is necessary; under the conditions of acidity and dilution laid down, the process of reduction is complete within ten minutes after the introduction of the thiosulphate; moreover, former experience† shows clearly the danger of submitting mixtures of sodium thiosulphate and acid to temperatures much above the ordinary. On the other hand, artificial reduction of temperature tends to retard the action to an impossible degree. Thus, in an experiment it took five minutes to reduce 0·0500 of ferric oxide at 21° C. completely at a dilution of 200$^{cm^3}$ and in the presence of $\frac{1}{2}$$^{cm^3}$ of hydrochloric acid; under conditions otherwise precisely similar excepting that the temperature was lowered to 0° C., the action lingered forty-five minutes.

* Zeit. f. Anal. Chem., i, 214. † This Journal, vol. vii, 287.

Lastly, the question as to the excess of thiosulphate necessary to complete the reduction within a reasonable time must be considered. In nearly all previously recorded experiments the excess of thiosulphate was not less than 15^{cm^3} of the $\frac{n}{10}$ solution. The following table shows the effect of diminishing this excess.

TABLE III.

	Fe_2O_3 taken. grms.	Fe_2O_3 corrected. grms.	Dilution. cm^3.	HCl. cm^3.	$Na_2S_2O_3$ in excess. cm^3.	Fe_2O_3 found. grms.	Error. grms.
22.	·0250	·0250	400	¼	12·2	·0241	·0009—
23.	·0500	·0499	400	½	12·2	·0495	·0004—
24.	·0500	·0499	400	½	13·66	·0493	·0006—
25.	·1000	·0998	400	1	7·31	·0984	·0014—
26.	·1000	·0998	400	1	7·63	·0972	·0026—
27.	·1001	·0999	400	1	12·88	·1007	·0008+
28.	·1498	·1495	600	1½	11·97	·1475	·0020—
29.	·1996	·1992	800	2	12·43	·1980	·0012—

From the above experiments taken in connection with those of Table I it is clear that there should always be present an excess of at least 15^{cm^3} of the $\frac{n}{10}$ solution of sodium thiosulphate. If the quantity of hydrochloric acid is kept very low there is no reason why this excess of thiosulphate could not be considerable without producing any disturbing effect. Practically, however, the presence of an excess between the limits of 15^{cm^3} and 35^{cm^3} of the $\frac{n}{10}$ solution has been found to give the most satisfactory results.

To recapitulate then, it has been shown that the dilution must be at least 400^{cm^3} for each ·1 of a grm. of iron oxide present, that the quantity of acid should never exceed 1^{cm^3} of the strong acid to each 400^{cm^3} of water, that the time of reduction must be short to avoid progressive oxidation, that the temperature of the solution should be kept at the normal temperature of the atmosphere, and finally that the excess of sodium thiosulphate present should never be less than 15^{cm^3} of the $\frac{n}{10}$ solution. In the case of large dilution the use of freshly boiled water is recommended so as to avoid the reoxidizing effect of the air upon the reduced iron. In the experiments included in the following table, the above precautions were closely adhered to and manifestly satisfactory results were obtained.

TABLE IV.

	Fe_2O_3 taken. grms.	Fe_2O_3 corrected. grms.	Dilution. cm^3.	HCl. cm^3.	Excess $Na_2S_2O_3$. cm^3.	Fe_2O_3 found. grms.	Error. grms.
30.	·0125	·0125	200	$\frac{1}{8}$	23·5	·0125	·0000
31.	·0250	·0250	400	$\frac{1}{4}$	21·98	·0250	·0000
32.	·0250	·0250	400	$\frac{1}{4}$	17·	·0250	·0000
33.	·0250	·0250	400	$\frac{1}{4}$	17·	·0250	·0000
34.	·0500	·0499	400	$\frac{1}{2}$	24·	·0498	·0001—
35.	·0500	·0499	400	$\frac{1}{2}$	19·	·0498	·0001—
36.	·0500	·0499	400	$\frac{1}{2}$	15·1	·0497	·0002—
37.	·0500	·0499	400	$\frac{1}{2}$	19·	·0498	·0001—
38.	·1001	·0999	400	1	23·1	·0993	·0006—
39.	·1001	·0999	400	1	17·93	·0997	·0002—
40.	·1001	·0999	400	1	22·92	·0997	·0002—
41.	·1001	·0999	400	1	18·	·0997	·0002—
42.	·1001	·0999	400	1	16·	·0996	·0003—
43.	·1498	·1495	600	$1\frac{1}{2}$	23·26	·1493	·0002—
44.	·1498	·1495	600	$1\frac{1}{2}$	16·66	·1493	·0002—
45.	·1498	·1495	600	$1\frac{1}{2}$	26·87	·1475	·0020—
46.	·1996	·1992	800	2	22·38	·1990	·0002—
47.	·1996	·1992	800	2	17·29	·1999	·0007+
48.	·1996	·1992	800	2	22·20	·1991	·0001—
49.	·4045	·4037	1600	4	16·03	·4042	·0005+
50.	·4045	·4037	1600	4	16·2	·4023	·0014—
51.	·4018	·4010	1600	4	16·34	·4007	·0003—
52.	·5051	·5041	1800	4	15·27	·5026	·0015—

As seen in the table this process is very accurate, especially in the use of small amounts of ferric oxide. The introduction of cupric sulphate as recommended by Oudemanns, or of sodium salicylate according to Haswell's method, seems to be unnecessary and only complicates the process.

In treating ferric oxide, the following method of procedure is recommended. Dissolve an amount not exceeding 0·2 grm. of the oxide in hydrochloric acid, evaporate to a pasty mass, dilute to about 800^{cm^3} with freshly boiled water, add a drop of potassium sulphocyanide, and into this solution run 50^{cm^3} of approximately $\frac{n}{10}$ sodium thiosulphate; allow the liquid to stand until perfectly colorless and determine the excess of thiosulphate by $\frac{n}{10}$ iodine and starch. For quantities of iron oxide up to 0·2 of a grm. this process is quick and most accurate: when care is taken to preserve the relations of acidity and dilution, twice the amount of ferric oxide mentioned above may be handled.

In conclusion I wish to thank Prof. F. A. Gooch for his kind advice and many suggestions.

ART. V.—*The Mouth of Grand River;* by E. H. MUDGE.

REFERENCE to a map of Michigan will show that the mouth of Grand River, as commonly understood, is at Grand Haven, where the chief river of the State loses itself in the waters of Lake Michigan. But there is another point seventy miles inland which to one familiar with the old river valley, with its varied and interesting history during recent geological times, presents itself to the mind as the mouth of Grand River in a very interesting sense.

The history of this old river valley, in the days when it served as an outlet for the glacial lake Saginaw, has become quite well known to the geological world through the labors of several enthusiastic investigators, notably Mr. Frank B. Taylor, whose final solution of the chief problem here presented was first made public through a paper* read before the Geological Society of America in 1896. To understand thoroughly the matters under discussion in the present paper, a reading of Mr. Taylor's able paper is recommended, especially pages 48 to 54. The point of chief importance to the present discussion is that at one time a great glacial stream, three-fourths of a mile in width as indicated by the old valley, flowed across the peninsula from Lake Saginaw to Lake Chicago. At the point above referred to, in the eastern part of Ionia County (see map accompanying Mr. Taylor's paper), this great river received the waters of another stream, which had its rise far to the south, almost within shouting distance of the Indiana line. This stream was the upper part of what is now known as Grand River. There is no reason to believe that it was ever any larger than at present, and it was therefore but a branch of the great glacial river, with its mouth at the point above indicated.

Long ago the sources of the glacial river failed, and the wide valley with its record-bearing deposits was laid bare to await the time when the inquisitive geologist should investigate its secrets. Among other things thus rendered accessible are the fine river-mouth deposits about this old mouth of Grand River.

The Pewamo outlet (as the glacial river has been named by Mr. Taylor) was relatively a sluggish stream, its fall being something less than one foot per mile, while the fall of the upper Grand is three or four times as great. The surface of

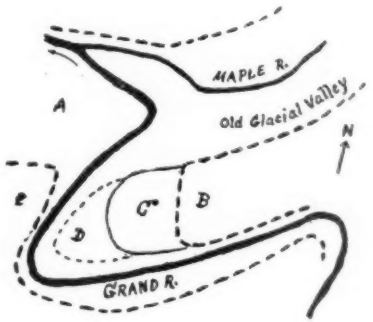
* "Correlation of Erie-Huron Beaches with Outlets and Moraines in Southeastern Michigan," by Frank Bursley Taylor, Bulletin of G. S. A., vol. viii, January, 1897.

the country through which the latter flows is composed chiefly of loose drift materials, well calculated to supply to the stream large quantities of sediment, which, in obedience to a well known law of river action, would be precipitated at the point where the stream joined its waters with a body of still water or with a slower stream. In this case such deposition took place at the old mouth, and in consequence the wide valley here exhibits some interesting features.

The first of these to attract the attention of the observer is the curious meanderings of the two streams before a junction is effected. The Maple River, which occupies the old valley above this place, flows in a channel near the center of the same until a point opposite the old mouth is reached, when it veers over against the north wall of the valley (see map). The Grand, coming in from the south, makes its way through the mass of old sediments (actually flowing "up stream" with reference to the glacial valley, in order to do so), until within a few rods of the Maple, and then turns down the valley and flows nearly parallel with the Maple for some distance before forming a junction, beyond which the united streams keep close to the north side of the valley for four or five miles. It is readily seen that these peculiar conditions are due to the clogging of the valley, in the vicinity indicated by A on the map, by the abundant sediment brought down by the Grand. There is a marked contrast between this area of abundant sediment and that a little farther to the east on the opposite side of the Grand. The latter is subject to overflow during freshet periods, while the former is built up to a considerable height above high water. These conditions continue for about two miles down the valley, along the south side, the filling being so extensive that the steep bluffs are partly obliterated, being replaced by a more gentle declivity. A well-defined terrace, which will be again referred to farther on, also tends to destroy the bluff feature. Immediately above the mouth the bluffs are again steep and prominent.

Some terraces about the old mouth are of considerable significance. When Mr. Taylor examined the valley of the Pewamo outlet in 1896, he called on the writer at Ionia and together we searched in that vicinity for terrace remnants that might indicate the height of the water in the glacial stream, but found nothing of a definite character. I suggested to him that such terraces may have been sheltered and preserved about this old river mouth, but rain and lack of time prevented a visit. I have since had opportunity to study the locality, and am able to report several well-defined and quite extensive terraces.

In the days of the glacial outlet there appears to have been here a small embayment, half a mile or more in extent in either direction. This embayment and the terraces now existing within it are indicated on the accompanying map. The heavy broken line indicates the bluff margin of the main valley and the embayment. From the high ground at B one descends abruptly to the terrace C. This is perhaps the most important of the series. Its elevation has not been measured, but it may be said roughly to occupy a place about midway between the top and the bottom of the main valley. Its surface is smooth and even, with abundant coarse sand and gravel upon it—a sort of gravel loam—together with patches of vegetable mould. South of this terrace, on the opposite side of the Grand,



there is a corresponding terrace, sharply defined but only a few rods in width—a mere shelf against the face of the steep bluff. Terrace C inclines gently to the west, the total descent being perhaps 15 or 20 feet. This terrace is so definite a feature of the locality that one can scarcely resist the conclusion that it marks a stage of the ancient river. An eye estimate of its elevation, made from the railway station across the valley at Muir, places it about 20 or 30 feet above the station, which is 656 feet above sea-level. An elevation of from 675 to 685 feet may therefore be taken as a fair estimate.

The nearest point to which Mr. Taylor traced the old beaches of the Saginaw Valley is at Maple Rapids, 25 miles away. At that place he assigns to the Forest beach, the lower of the two, an approximate elevation of 680 feet. The correspondence between this figure and the estimated elevation of terrace C is so close that the conclusion that they are equivalents is quite irresistible.

The descent from C to D is well marked but not steep. The surface is flat and several feet above the annual overflow of the Grand. It apparently corresponds in height with the sediment-filled area at A, and its presence appears to have no special significance. The two terraces described form the site of the village of Lyons.

A third terrace, high above the others, is found across Grand River to the west, covering a considerable area at E. Its limit is marked by a line of low hills, beginning near the big bend of the Grand and extending across northwest to the main valley. It is this terrace that helps to modify the bluff feature in this vicinity, above referred to. It may quite likely be correlated with a high terrace remnant seen at Ionia and with others mentioned by Mr. Taylor, but it is, I think, much better defined and more extensive than any of its probable equivalents hitherto observed. Its position is such that it may be considered tentatively as a portion of the Duplain beach, which Mr. Taylor traced as far as Maple Rapids.

The evidence from this little embayment is on the whole quite in harmony with that from other sources, in its bearing upon the history of the Pewamo outlet.

Lyons, Mich.

ART. VI. — *Electrical Measurements;* by HENRY A. ROWLAND and THOMAS DOBBIN PENNIMAN.*

IN a previous article† mention was made of some work then being carried on at the Johns Hopkins University to test the methods for the measurement and comparison of self-inductance, mutual inductance, and capacity there described.

In the present paper, there will be given an account of the experiments performed with some of the methods described in the previous article, together with a method for the direct measurement of the effect of electric absorption in terms of resistance.

The methods that were tried were 25, 26, 9, 3, 12 and 6.

APPARATUS.

Description of the electrodynamometer, dynamos, coils, condensers, resistances and connections used in the experiments.

Electrodynamometer. — The electrodynamometer was one constructed at the University, having a sensitiveness, with the coils in series, of 1 scale division deflection for ·0007 ampere.

The hanging coil was made up of 240 turns of No. 34 copper wire B and S gauge. The coil was suspended by a bronze wire connected with one terminal of the coil. The other terminal of the coil was a loop of wire hanging from the bottom of the coil and attached to the side of the case; both the suspension and the loop were brought out to binding posts. The resistance of the coil with suspension was 21·7 ohms.

The fixed coils were made up of 300 turns each of No. 30 B and S gauge copper wire. The coils were wound on cup-shaped metal forms and soaked in a preparation of wax. The form was then removed and the coils placed a radius apart as in the arrangement of Helmholtz.

Dynamos.—There were two dynamos used, a Westinghouse alternator, and a small alternating dynamo constructed at the University. The Westinghouse dynamo was one having 10 poles so that each revolution of the armature produced 5 complete periods. The period of this dynamo was determined by taking the time of 1000 revolutions of the armature. This was accomplished by having the armature make an electric connection with a bell every 200 revolutions and taking the

* This Journal, iv, p. 429, December, 1897; Philosophical Magazine, January, 1898.

† Abstract of Thesis for the degree of Ph.D.

time of 5 of these. The taking of the speed during every experiment gave more regular results, as the speed was constantly changing, the dynamo being run by the engine in the University power-house when it was subject to great change of load. This dynamo had a period of about 132 complete periods per second.

For the production of a current of less period than that of the Westinghouse, the small alternator constructed at the University was used. This dynamo was run by a small continuous Sprague motor. The armature of the small alternator consisted of 8 coils, which coils were fastened flat on a german silver plate, the plate revolving between 8 field pieces producing 4 poles. The object of having the coils of the armature on a metal plate was to secure a nearly constant speed. The metal plate produced a load that varied as the velocity and due to induced currents in the plate. The varying load, depending on the velocity of the moving plate, produced a nearly constant speed, which rendered unnecessary the constant taking of the speed. When this dynamo was used, the speed was only determined two or three times during a series of readings or experiments. The average of these determinations was taken as the speed during the whole series of experiments under consideration.

Coils.—The coils whose inductances were determined were all made in the same way, being wound on a metal form and soaked in a preparation of wax. When the wax was hard the metal form was removed. This enabled the coils to be placed close together, as their sides were flat and smooth. The coils all had the same internal and external diameter, but their width varied, that being determined by the number of turns that were desired.

Coils. P_1. External diameter $35{\cdot}46^{cm}$, internal diameter $23{\cdot}8^{cm}$, was made up of about 1200 turns of No. 16 B and S gauge single covered cotton copper wire, roughly wound; the turns were not smooth; self-inductance as finally determined ·566 henry.

P_2. Same dimensions. Turns were put on evenly. The number of turns was 1300 of No. 16 B and S single covered cotton copper wire. Self-inductance ·724 henry.

A. Same internal and external diameters as P, but the width was $4{\cdot}3^{cm}$. Number of turns 3700 No. 20 B and S gauge single covered cotton copper wire. Self-inductance as determined 5·30 henrys.

B_1B_2. This coil was made by winding two wires in parallel and all four of the terminals brought out to binding posts. Thus the coils could be used as two single coils, when the coils will be denoted by the symbols B_1 and B_2 as the case may be,

or as a single coil, the coils B_1 and B_2 being joined up in series or in parallel. The dimensions of the coils B_1 B_2 were the same as A. Each of the coils B_1 and B_2 were made up of 1600 turns of No. 22 B and S single covered cotton copper wire. The self-inductance of these coils taken separately when compared with P, which was determined absolutely, was nearly 1 henry. On this account B was taken as being 1 henry, and the other coils were compared with it as a standard.

C. Same dimensions as P_2. Number of turns 1747 of No. 22 B and S single covered cotton copper wire. Self-inductance as determined 1·30 henrys.

Condensers.—2 and 3. Two paraffined paper condensers that had a capacity of 2 and 3 microfarads respectively.

$\frac{1}{3}$d Troy. A $\frac{1}{3}$d microfarad standard mica condenser built by the Troy Electric Co.

$\frac{1}{3}$d Elliott. A $\frac{1}{3}$d microfarad standard mica condenser built by Elliott Bros.

Resistances.—The resistances used in the experiments were of two kinds, those wound with double wire so as to have no self-inductance, as the ordinary resistance box, and those wound on frames or cards which had some small self-inductance, but almost no electrostatic capacity. The resistances which had self-inductance are called open resistances to distinguish them from resistance boxes, and were of different kinds and dimensions.

Sources of Error and Experimental Difficulties.

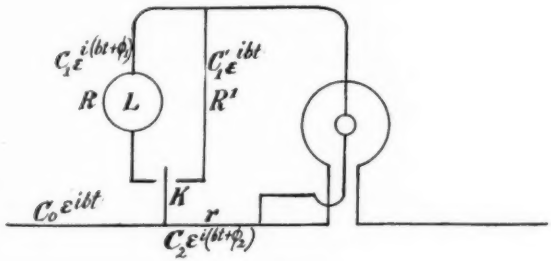
In all work with alternating currents there are two great sources of error that have to be guarded against. These are the errors that may arise from the inductance of one part of the apparatus on another, as, for example, the direct induction of a coil in the circuit on the coils of the electrodynamometer, and the effect of the electrostatic capacity of the leads and connections. In connecting the coils great care had to be taken to avoid the effect of electrostatic action of the leads and connections. For if there was a current of very considerable magnitude, the difference of potential between the terminals of the coil might be great. If the connections under these circumstances were made with double wire, as is customary, a great error was introduced due to the electrostatic capacity of the leads. The error was sometimes as much as 7 per cent (see method 24). This error could be shown to be due to the electrostatic action of the leads by shifting a resistance in circuit with the coil in question from one end of the double wire to the other. The effect of this was to still further increase the difference of potential between the leads, and this increased the error. Experiments of this character showed the necessity

of using open leads and open resistances having little or no capacity in all cases in which the coils experimented on and the resistance boxes used in their determination have a current of any considerable magnitude passing through them. In several of the following methods constancy of current was necessary. This was accomplished by various means that will be described in their actual application.

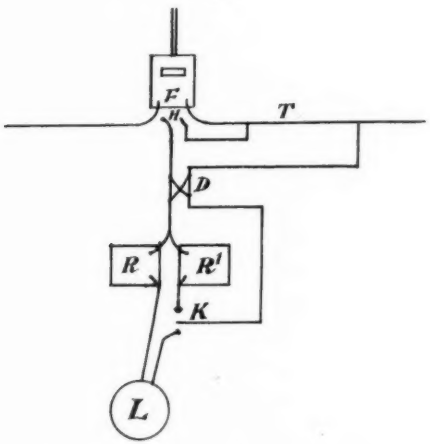
Methods.

The methods that were tried were 25, 26, 9, 3, 12 and 6 described in this Journal, December, 1897.*

1.



2.



Method 25.—Method of equal deflections. Absolute method for the determination of self-inductance or capacity in terms of electromagnetic units.

* Phil. Mag., January, 1898.

In this method the hanging coil is shunted off the fixed coils circuit, and this with a non-inductive resistance in circuit with the hanging coils is made the same as that of a certain inductive resistance in circuit with the hanging coil. The connections are made as in the figs. 1, 2, where $C_0\epsilon^{ibt}$, $C_1\epsilon^{i(bt+\phi_1)}$, $C_2\epsilon^{i(bt+\phi_2)}$ are currents. R, R′, r, resistances. They represent the entire resistance of their respective branches. L represents self-inductance of the coil by which it is placed. The outer circle in fig. 1 represents the fixed coils and the small circle the hanging coil of the electrodynamometer. In fig. 2 the terminals of the fixed and hanging coils are represented by F and H. D is a reversing commutator. K is a key to send the current first through the inductive and then through the non-inductive resistance. $b = 2\pi n$, n = complete alternation per sec. This is the general notation adopted throughout the article.

The quantity to be found is $C_0C_1 \cos \phi_1$, which is proportional to the deflection of the hanging coil in the two positions of K.

In one position

$$C_1\epsilon^{i(bt+\phi_1)}(R+ibL) = C_2\epsilon^{i(bt+\phi_2)}r = (C_0\epsilon^{ibt} - C_1\epsilon^{(ibt+\phi_1)})r$$

Therefore

$$C_0C_1 \cos \phi_1 = C_0 \frac{2r(R+r)}{(R+r)^2+b^2L^2} \propto D$$

In the other position of K

$$C_1'\epsilon^{ibt}R' = C'_2\epsilon^{ibt}r = (C_0\epsilon^{ibt} - (C_1'\epsilon^{ibt})r$$

Therefore

$$C_0C_1' = C^2_0 \frac{r}{R'+r} \propto D'$$

$\phi = 0$, as ϕ is an angle whose tangent is $\frac{bl}{R'}$ and $C = 0$ nearly.

In the case of equal deflection $D = D'$ and therefore

$$b^2L^2 = (R'-R)(R+r)$$

If capacity had been used in the place of self-inductance the formula would be

$$\frac{1}{b^2c^2} = (R'-R)(R+r)$$

If self-inductance and capacity were used in series

$$b^2\left(L - \frac{1}{b^2c}\right)^2 = (R'-R)(R+r)$$

The application of this formula to the measurement of self-inductance gave results that agreed to within the accuracy with which the period of the alternations could be determined.

That is, the results agreed to within about 1 per cent. In the determination of L the resistance in circuit R was varied from the least possible resistance as determined by the coils up to 1000 ohms and more, and the self-inductance was determined under these various conditions. These results agreed among themselves, and were apparently independent of the resistance in circuit with it. In the application of this method to the determination of capacity, however, great trouble was encountered, as the capacity apparently varied both with the resistance in circuit with it and with the period. This variation was regular for each period, the value derived depending on the resistance in circuit. This irregularity of derived value of the capacity led to the investigation and development of Maxwell's formula on the effect of absorption, a necessary characteristic of heterogeneous substances.

When the formula was deduced, as may be seen in the article already referred to, the absorption comes in as an added resistance, the resistance being constant for a given period. By an inspection of the results this was found to be the case. The finding of the resistance due to absorption in this method is one of approximation, but the values deduced compare very favorably with those determined by direct measurement, as will be seen later when various results are collected. In the actual experiments the condensers used were two paraffined paper condensers of about 2 and 3 microfarads. The currents used had different periods, as seen in the table following, where $n = 133, 53{\cdot}3, 31{\cdot}9$ and 14.

The process was to place in the condenser circuit a resistance R, and then to move the key K back and forth until R′ was found that gave the same deflection. D, fig. 2, was now reversed and the process repeated. This was repeated with different values of R and n and the apparent capacity. This gave great variation of apparent capacity with different values of R, which should not be the case, and, therefore, gave a means of finding the resistance due to absorption or absorption resistance, as we will designate, by approximation. As the effect of absorption is a resistance it is possible to find what resistance, if added to R, will make all the values of the capacity as determined for the different values of R the same. Therefore it should be the same for any two values of R. Calling the two values of R in the two cases R_1 and R_2 respectively and the two corresponding values of R′, R_1', and R_2', and let A be the added resistance due to absorption, the capacity should be the same in the two cases, or

$$\frac{1}{b^2c^2} = [R_1' - (R_1 + A)][R_1 + A + r] = [R_2' - (R_2 + A)][-R_2 + A + r]$$

$$\therefore A = \frac{(R_2' - R_2)(R_2 + r) - (R_1' - R_1)(R_1 + r)}{R_1' - R_2' - 2(R_1 + R_2)}$$

From this A is found for the period used. By doing this for a number of different values of R, the true value of A is approximated. A was thus found for the condensers 2 and 3 microfarads with different values of n. The calculations were again performed adding to the different values of R a constant resistance A. The capacity that was found when A is added to R is called the corrected capacity. In the table below are collected the corrected values of the capacities together with n and the resistance A.

Capacity	4·94	4·96	4·96	4·64	microfarads.
n	131·1	53·3	31·98	14·	complete alternations.
A	5·19	20·5	34·09	139·62	absorption resistance in ohms

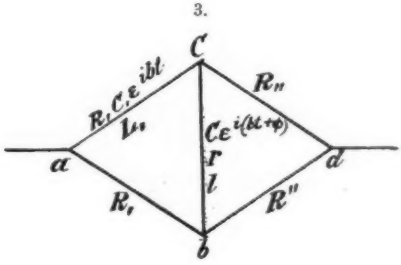
The last value of the capacity seems to be an error, possibly one of calculation. However, the results seem to show a nearly constant capacity, but a resistance increasing rapidly with decrease of period, as Maxwell's formula shows. The constant value of the capacity remains to be explained.

But in the above, determinations of absorption resistance are by approximation. Professor Rowland has, therefore, devised a method by which it can be measured directly. This method, with the results that have been derived by it, will now be given.

Method for the Direct Measurement of Absorption Resistance.

In a Wheatstone bridge (fig. 3) let the resistance of the different arms be denoted by $R_,$, R', $R_{,,}$, R'' and r. Let $R_,$ have in circuit a self-inductance $L_,$ and let r have in circuit with it a self-inductance.

3.



Let $C_,\epsilon^{ibt}$ be the current through $R_,$ and $C\epsilon^{i(bt+\phi)}$ be the current through r when a periodic electromotive force is applied to a and d in the figure.

Let $C_,'$ be the current through $R_,$ and C' be the current through r when there is a constant difference of potential between a and d. The ratio of the current in this case is

$$\frac{c'}{C_{,}'} = \frac{R''R_{,} - R'R_{,,}}{R'(R''+R_{,,}) + r(R'+R'')}$$

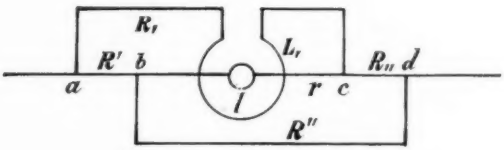
When a periodic electromotive force is applied to a and d, the ratio of the currents in this case is

$$\frac{c}{C_{,}} \epsilon^{i\phi} = \frac{R''R_{,} - R'R_{,,} + ibR''L_{,}}{R'(R''+R_{,,}) + r(R'+R'') + ibl(R'+R'')}$$

Separating the real and imaginary parts

$$\frac{c}{C_{,}} \cos\phi = \frac{(R''R_{,} - R'R'')[R'(R''+R_{,,}) + r(R'+R_{,,})] + b^2lL_{,}R''(R'+R'')}{[R'(R''+R_{,,}) + r(R'+R'')]^2 + b^2l^2(R'+R'')^2}$$

4.



If now the fixed coils of the electrodynamometer are placed in the $R_{,}$ arm of the bridge, and the hanging coil is placed in cross connection of the bridge, as in fig. 4, the different resistances may be adjusted until there is no deflection, in which case $\phi = 90°$ or $\cos\phi = 0$, therefore

$$(R''R_{,} - R'R_{,,})\,[R'(R''+R_{,,}) + r(R'+R'')\,] + b^2lL_{,}R''(R'+R'') = 0$$

$$\therefore R''R_{,} = R'R_{,,} - b^2lL_{,}\,\frac{R''(R'+R'')}{R'(R''+R_{,,}) + r(R'+R'')}$$

If in connection with L' a capacity C is added, the formula becomes, substituting for $L_{,}$, $L_{,} - \frac{1}{b^2c}$

$$R''R_{,} = R'R_{,,} - \left(b^2lL_{,} - \frac{l}{c}\right)\frac{(R''R'+R'')}{R'(R''+R_{,,}) - r(R'+R'')}$$

In most cases since l and $L_{,}$ are generally the self-inductances of the instruments the term $b^2\,l\,L_{,}$ can be neglected in comparison with $\frac{l}{c}$ and the equation becomes

$$R''R_{,} = R'R_{,,} + \frac{l}{c}\,\frac{R''(R'+R'')}{R'(R''+R_{,,}) + r(R'+R'')}$$

In this equation $R_{,}$ includes both the ohmic and the absorption resistance. The value of $R_{,}$ is determined in terms of known quantities, that is the resistance and l and C. It was not

necessary that l and C should be exactly known as the last term in the equation above plays the part of a correction term, and is in all cases below small and in some cases negligible. The capacities that were used in the experiments were the 2 and 3 microfarads, the $\frac{1}{3}$ microfarad Elliott condenser, and the $\frac{1}{3}$ microfarad Troy condenser.

Experiments—The process of experimenting was to apply a periodic electromotive force to a and d, and to adjust the different resistances until there was no deflection of the coil in

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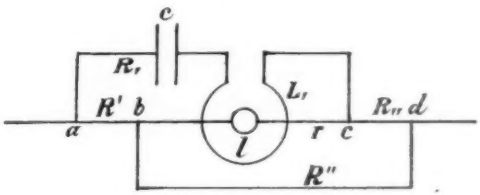


the same way as in the ordinary measurement of resistance on a Wheatstone bridge. The different resistances R′, R″, R,, and r being known, the apparent value of the resistance R, was found, and knowing the ohmic resistance of the R, circuit, the absorption resistance appears as the difference.

Some interest lies not alone in that the method is applicable, but that it confirmed the supposition that absorption resistance acts as an ordinary ohmic resistance in series in the circuit. This was confirmed by the fact that when condensers were in series and in parallel, their absorption resistances acted under these conditions like ohmic resistances, being increased in the one case and decreased in the other, and in the right ratio. This agreement was not exact, as the absorption resistance was extremely sensitive both to change of period and change of temperature. The great sensitiveness to change of temperature was shown either by letting the current go through the condensers for a little time, or placing the condensers before a hot air flue; in either case after cooling, the absorption resistance returned to its original value. The cooling was very slow, as there was very little radiation from the condensers inclosed in wooden boxes.

The results are now given for the condensers 2 and 3 microfarads. In the calculation of the results the last term of the equation, that is $\frac{l\,R''(R'+R'')}{c\,R'(R''+R_{,,})+r(R'+R'')}$ has been left out, as it was very small when condensers 2 and 3 microfarads were used.

CONDENSERS 2 AND 3 MICROFARADS IN PARALLEL.
n=134, l=·0007 ∴ last term negligible.

R″	R,	r	R′	R,	Resis. of R′ circuit in ohms.	Resistance due to absorption.
422·6	488·6	5457·3	347·9	39·29	33·77	5.30
1488·6	488·2	"	123·4	40·50	"	6·73
984·1	"	"	82·1	40·72	33·81	6·91
2671·6	"	"	22·5	41·116	"	7·30
423·0	"	"	357·3	41·237	"	7·42
5474·3	"	"	464·5	41·42	"	7·61
6734·	"	"	374·9	41·67	"	7·86
1 ohm in R″=¼ scale division.					"	
7486·	"	"	638·6	41·64	"	7·83
9466·	"	"	81·15	41·85	"	8·04

Condensers 2 and 3 placed before the register and heated for 1 hour:

7489·7	488·27	"	713·8	46·534	34·33	12·20

After standing 1½ hours in air at temperature of 12°·2 C. condenser has been open so that resistances have been cooled:

1240·5	487·8	"	109·	42·86	34·	8·86

After standing some little time:

7482·5	487·8	"	651·6	42·47	34·	8·49

The above table shows conclusively the heating of the condenser by the current, and the dependence of the absorption upon the temperature.

CONDENSERS 2 AND 3 IN PARALLEL. N=57·6.

R″	R,	R′	r	R,	R, in ohms.	A.
348·5	488·6	396·3	11020·7	55·61	33·77	21·84
7488·	"	849·2	"	55·41	"	21·64
"	"	844·1	4026·	55·07	"	21·30
3485·	"	396·1	"	55·58	"	21·81
						Average, 21·63
N=56·6 per second.						
3485·	200·24	976·7	4026·	56·00		22·23

Comparing these values with those found in the use of method 25 the agreement is at once apparent.

N=	134·	131·	57·6	56·6	53·
Method 25		5·19			20·5
Direct measurement.	5·30 cold 7·00 warm		21·63	22·23	

It should be remembered, in comparing the results, that the values obtained by Method 25 would naturally be smaller than those found by direct measurement, as in Method 25 the current going through the condensers was extremely small; there was therefore practically *no* heating.

The experiments that confirm the mathematical theory that the absorption resistance could be treated as ordinary ohmic resistance were performed with the two condensers, $\frac{1}{3}$ Troy and $\frac{1}{3}$ Elliott microfarad condensers. These are next given.

In these results it was necessary to take into account, in the calculation of the apparent value of $R_{,}$, the last term of the equation, that is

$$\frac{l}{c}\,\frac{R''(R'+R'')}{R'(R''+R_{,})+r(R'+R'')}$$

$\frac{1}{3}$ Troy and $\frac{1}{3}$ Elliott in series, 1 o'clock.

R''	$R_{,}$	R'	r	Apparent value of $R_{,}$	Ohmic resistance of $R_{,}$	Absorption resistance A.
4751·8	499·9	404·8	4754·	43·141	34·143	8·998
$\frac{1}{3}$ Troy, 2 o'clock.						
4750·	497·75	352·4	"	37·288	34·144	3·144
$\frac{1}{3}$ Elliott, 2.45 o'clock.						
4749·3	497·67	390·3	"	41·260	"	7·116
$\frac{1}{3}$ Troy and $\frac{1}{3}$ Elliott in parallel, 4 o'clock.						
4749·3	497·6	350·23	"	36·94	34·15	2·79
$\frac{1}{3}$ Troy and $\frac{1}{3}$ Elliott in series.						
4748·5	497·55	418.15	"	44·612	34·12	10·492

Calculating what the absorption resistance should be for $\frac{1}{3}$ Troy and $\frac{1}{3}$ Elliott in series, from the absorption resistances of the two condensers when determined separately, it is equal to 10·26 ohms, which is greater than the first and less than the last value above, showing that the condensers were heating during the experiments. Calculating the absorption resistance of $\frac{1}{3}$ Troy and $\frac{1}{3}$ Elliott in parallel in the same way, it is equal to 2·209 ohms, which is less than the value afterwards obtained by experiment for the same reason.

The method was shown not to be based on any false supposition, by substituting in place of the condenser a coil of known self-inductance. When this was done the value of $R_{,}$ as calculated from the other resistances and the self-inductances should be the same as the actual ohmic resistance of the circuit.

This was tried with two coils P_2 and A and the agreement was remarkably close, as seen in the next table.

Coil P used in place of condenser in the $R_{,}$ circuit:

R''	$R_{,}$	R'	r	Deduced value of $R_{,}$	Actual value of $R_{,}$
474·9	487·8	758·2	5457·	77·86	77·8
Coil A in place of condenser in the $R_{,}$ circuit:					
474·9	487·8	218·3	"	224·12	223·9

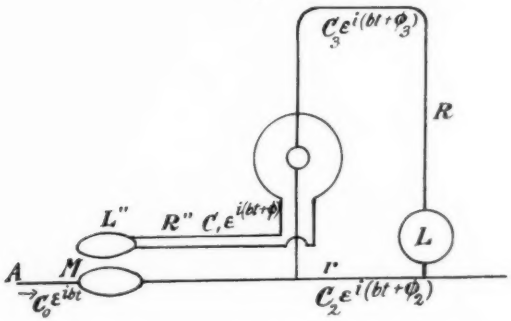
In these experiments great care was taken that the measurements of the resistances were performed immediately after the adjustment. In this way the actual resistances at the time of the experiment were obtained, and so the effect of the heating by the current was somewhat eliminated.

Methods 26, 9 and 3 give good results, but the methods that gave the most satisfaction were Methods 12 and 6, Method 12 being for the comparison of two self-inductances and Method 6 for the comparison of a self-inductance with a capacity. These give some remarkable results, the theory and deductions of the methods being as follows:

Method 12—Zero method for the comparison of two self-inductances.

Let the connections be made as in the figure where the hanging coil and the fixed coils are in two distinct circuits.

6.



Let $C_0\epsilon^{ibt}$ etc. be the currents, A′ and A″ reversing commutators, R″, R and r the resistance of the different circuits, L″ and L the self-inductances, M the mutual inductance of the coils B_1 and B_2 by which it is placed. When a periodic electromotive force $a\epsilon^{ibt}$ is applied to A, B the quantity to be found is $C_1 C_3 \cos(\varphi_3 - \varphi_1)$ where $\varphi_3 - \varphi_1$ is the difference of phase.

The current in the R″ circuit is then

$$C_1\epsilon^{i(bt+\phi)} = \frac{ib\mathrm{M}C_0\epsilon^{ibt}}{\mathrm{R}'' + ib\mathrm{L}''} \qquad (1)$$

The current in the R circuit is

$$C_3\epsilon^{i(bt+\phi_3)}(\mathrm{R}+ib\mathrm{L}) = C_2\epsilon^{i(bt+\phi_2)}\, r$$

$$\therefore\ C_3\epsilon^{i(bt+\phi_3)}\frac{\mathrm{R}+r+ib\mathrm{L}}{r} = C_0\epsilon^{ibt}$$

Substituting the value of $C\epsilon_0^{ibt}$ in equation (1) and simplifying, it becomes

$$C_1\epsilon^{i(bt+\phi)} = C_2\epsilon^{i(bt+\phi_2)}\frac{-b^2LM + ibM(R+r)}{R''r - ibL''r}$$

Therefore the deflection is proportional to

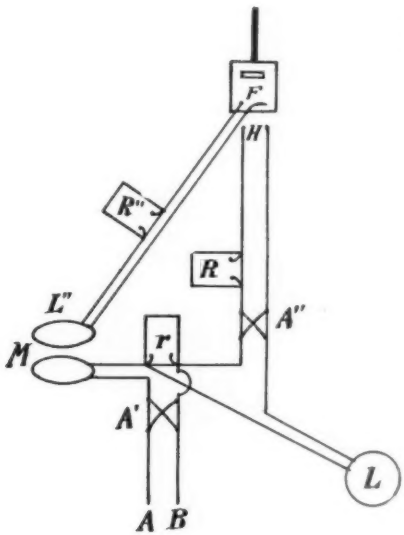
$$Da\,C_1C_2\cos(\phi_2\phi_1) = C_2^2\,\frac{-b_2LMR''r + b^2L''M\,r(R+r)}{R''^2r^2 + b^2L^2r^2}$$

where D is the deflection. Therefore the condition for zero deflection is

$$-b^2LMR''r - b^2L''M\,r(R+r) = 0$$

$$\therefore \frac{L}{L''} = \frac{R+r}{R''}$$

7.



The condition therefore of zero deflection is independent of M. But M is one of the factors of the electromotive force in the R'' circuit, and on it therefore depends the sensitiveness, as it determines the current through the R'' circuit. In the first figures of this method the fixed coils are in the R'' circuit, and the hanging coil in the R circuit, but this is not necessary, as the fixed and hanging coils can be reversed. The choice of which of the above arrangements should be used depends on

the impedances of the two circuits, as other things being equal the smaller current should go through the hanging coil.

Experiments—The coils used in the experiments were coils P_1, P_2, C, B_1, B_2, and A, which coils are described on page 36. From the dimensions of P_2 and its self-inductance as found by Method 25, B_1 was designed to have a self-inductance of one henry. This will be shown to be nearly the case. For ease of comparison B_1 has been taken in the calculations of the results as being equal to one henry, and the other coils were compared with this coil as a standard.

In these experiments the connections were made as in the figure 47, the coil B_1 that was taken as the standard being placed in circuit with the fixed coils of the electrodynamometer as L″ and the resistance of this circuit was unaltered during the experiments in any particular series. The coils whose self-inductances were to be determined were placed in the hanging coil circuit and the resistance R was changed until there was no deflection. The resistance of the two circuits, R″ and R+r were then measured by a Wheatstone bridge.

The resistance r was in all cases small in order that $C_0\varepsilon^{ibt}$ should be large, and therefore by induction $C_1\varepsilon^{i(bt+\phi)}$ the current through the fixed coils was made large and the instrument sensitive. The method being very accurate, as will be seen later, great care had to be used to eliminate all sources of error, as for example, electrostatic action. In the first trial of the method small differences were noticed in the ratio of two self-inductances, depending both on the resistances used, and also on the connections of the coils, whether the leads were double, single, long or short. The same variation was noticed when several coils were joined in series and compared with another coil, and when these coils were compared separately and their sum taken.

This irregularity led to an investigation of the effects of various resistances and connections in one of the circuits, the other circuit being unaltered. A little farther on, the variation in the deduced value of the self-inductance of one of the coils, when different resistances and leads were used, will be given, which variation was caused by the electrostatic action of the connections, etc. (Page 37.)

The necessity of eliminating electrostatic action made obligatory the use of open resistances which had small self-inductances. These resistances were of three kinds—resistances in the form of spirals, resistances wound on thin strips of mica-nite or paper, and those wound on open frames; see page 37.

The self inductance of the first and second classes of resistances was very small, as in one case there were only a few turns, and in the other the cross-section was very small.

The third class were those wound on frames whose self-inductances were calculated. There were several resistances of 2000 ohms each, whose self-inductances were ·0000436 henry, which would hardly affect the phase of the current or the impedence of the circuit.

These coils were subdivided into resistances of various amounts. Another frame resistance used was of 7463 ohms divided into parts of about 250 ohms each. The self-inductance of the entire 7463 ohms was ·000105 henry.

As the open resistances were not divided into small amounts it was necessary to use resistance boxes for adjustment; as few ohms as possible were used in each case.

From the fact that the coils of the electrodynamometer had self-inductance a correction was introduced in order that the ratio of the resistances should give the ratio of the self-inductances of the coils direct.

The value of this correction in ohms was calculated as follows:

Calculation of connection due to fixed and hanging coils.

Self-inductance of fixed coils $= f = ·0164$ henry
" " " hanging coil $= h = ·0007$ "

Correction due to fixed coils. From an inspection of the tables it is seen that

$$\frac{L}{B_1+f} = \frac{R+r}{R''}, \text{ or } \frac{L}{1·0164} = \frac{R+r}{902}$$

where L is the self-inductance of some coil and $R+r$ is the corresponding resistance. B_1 is taken as equal to 1 henry

$$\therefore \frac{L}{R+r} = \frac{1·0164}{902}$$

But the comparison of L with $B_1 = 1$ is wanted, therefore both numerator and denominator of $\frac{1·0164}{902}$ are divided by 1·0164 or

$$\therefore \frac{L}{R+r} = \frac{1 = B_1}{887·45}$$

$$\therefore \frac{L}{B} = \frac{R+r}{887·45}$$

That is, the self-inductance ·0164 henry of the fixed coils produced a correction of $887·45 - 902 = -14·55$ ohms, which must be applied to the R'' circuit if the self-inductance of that circuit is to be considered as 1 henry.

Correction due to hanging coil. The self-inductance = ·0164 henry of the fixed coils gives a correction of −14·55 ohms, therefore the self-inductance ·0007 henry of the hanging coil gives a correction of −·62 ohms to the R+r circuit. Applying these corrections, the results obtained for the several coils under various conditions are given below. The results are given in the following order.

First. The values are calculated using double leads in the circuits but open resistances as far as possible.

Second. The variation of the apparent value of the self-inductance of one of the coils with different positions of the coil, resistances, and different kinds of leads.

Third. Short leads separated about 6 inches and crossed, used with all the coils except B_1.

Fourth. Open leads and open resistances in the determinations. In the table R″ was open resistance plus the resistance of coil B_1 and fixed coils of instrument. R+r was made up of the small coil and open resistance plus the amount in the Queen ordinary resistance box.

After all the inductive effect of the leads was removed and the ordinary resistance box used as little as possible, there was a different value obtained for the ratio of the self-inductances dependent on the position of the reversing commutator A′. With all the coils used the greater value occurred with the same position of A′. This was due to the electrostatic action between the coils B_1 and B_2, for if the terminals of the coil B_2 and the commutator A′ were reversed at the same time, there was no change in the value of the ratio of the inductances. This showed that it was dependent on the coil itself and not on the leads and it could therefore not be eliminated.

It is to be noticed that the values obtained for the lower number of alternations are always greater than those found with the higher number of alternations. This was caused by the electrostatic action of the turns of the coil on each other. In the case of the coil P_2 this effect would be caused by supposing a capacity of ·0007 microfarads shunted across the terminals.

The results are now given comparing the different coils with B_1 as a standard and equal to 1 henry.

DOUBLE LEADS OF BELL WIRE AND OPEN RESISTANCES.

r = 106 ohms, n = 45 complete periods per second.

Coils.	R″.	Correc.		Queen.	R+r.	Correc.	Average.	Com. A′.	Ratio.
P_1+P_2									
+C	901·6	−14·55	887·05	292	2300·2	−·62	2304·9	1	2·5983
"	"	"	"	310	2311·0	"		2	
C	"	"	"	19	1158 3	"	1159·0	1	1·3099
"	"	"	"	22	1161·2	"		2	
C+P_1	"	"	"	103	1659·	"	1661·2	1	1·8727
"	"	"	"	109	1664·8	"		2	

Coils.	R″.	Correc.		Queen.	R+r.	Correc.	Average.	Com. A′.	Ratio.
C+P$_2$	901·6	−14·55	887·05	92	1800·2	−·62	1802·6	1	2·0288
"	"	"	"	99	1806·5	"		2	
A	901·7	"	887·15	149	4776·5	"	4786·5	1	5·3956
"	"	"	"	196	4818·0	"		2	
Current increased about 2½ times.									
A	"	"	"	141	4787·0	"	4781·3	1	5·3898
"	"	"	"	184	4807·	"		2	
A+C	901·6	"	887·05	211	5936·	"	5958·3	1	6·7170
"	"	"	"	264	5982·	"		2	
A+C×P$_2$	"	"	"	51	6575·5	"	6602·5	1	7·4430
"	"	"	"	104	6631·0	"		2	
A	902·	"	887·45	158	4778·9	"	4795·25	1	5·4036
"	"	"	"	192	4813·	"		2	
P$_1$+P$_2$	"	"	"	183	1146·5	"	1146·7	1	1·9922
"	"	"	"	186	1148·5	"		2	
P$_2$	"	"	"	7	643·15	"	642·67	1	·7242
"	"	"	"	8	643·6	"		2	
P$_1$	"	"	"	91	502·5	"	502·16	1	·5658
"	"	"	"		503·1	"		2	

DOUBLE LEADS. n = about 133 complete alternations per sec.

Coils.	R″.	Correc.		Queen.	R+r.	Correc.	Average.	Com. A′.	Ratio.
P$_1$	901·9	−14·55	887·35	90+s	500·4	+·62	499·69	1	·5631
"	"	"	"	"	500·23	"		2	
P$_2$	"	"	"	3	639·35	"	638·85	1	·7198
"	"	"	"	4	639·6	"		2	
A	901·87	"	887·32	?	4742·2	"	4750·48	1	5·3537
"	"	"	"	133	4760 0	"		2	
C	901·9	"	887·35	44	1151·4	"	1150·94	1	1·2970
"	"	"	"	44	1151·4	"		2	

In the above determinations the coils were arranged in the way as indicated in the figure having leads of double bell wire.

A SERIES OF DETERMINATIONS OF A UNDER VARIOUS CONDITIONS.

Open resistance R on table (original position).

Coils.	R″.	Correc.		Queen.	R+r.	Correc.	Average.	Com. A′.	Ratio.
A	902·0	−14·55	887·45	149+s	4776·5	−·62	4786·58	1	5·3936
"	"	"	"	196+s	4818·	"		2	
"	901·95	"	887·4	?	4783·5	"	4795·38	1	5·403
"	"	"	887·4	190+s	4808·5	"		2	
Open resistance R moved up to coil A (b_1).									
"	"	"	"	?	?	"			
"	"	"	"	?	4518·	"	4517·38	2	5·0905
Open resistance R moved to the other side of A (b_2).									
"	"	"	"	144+s	4518·	"	4518·88	1	5.0922
"	"	"	"	147+s	4521·	"		2	

Coil A placed in P$_1$ position and open resistance R restored to its position, and 159′ of double wire added to the circuit.

Coils.	R″.	Correc.		Queen.	R+r.	Correc.	Average.	Com. A′.	Ratio.
A	901·95	−14·55	887·4	547·+4129		−·62			
					547	"		1	
					4676		4693·38	2	5·2888
"	"	"	"	583+4129					
					583				
					4712				

Coil A at end of double wire 69′+159′=228′ long.

"	"	"	"	607+4129					
"	"	"	"		607				
					4736				
				634+4129					
					634				
					4763				

New leads placed in B_1 circuit, the wires were about 6″ from each other.

"	902·6	"	888·05	569+4129					
"	"	"	"		569				
					4698				
				594+4129			4709·88	1	5·3038
					594			2	
					4723				

Open resistance placed next Coil A.

"	"	"	"	663+4129			4791·3	1	5·3956
					663		4292·	2	
"	"	"	"		4292		·7		
							0·6		

In the following all connections were made with open leads, and open resistances were used.

Period.	Coils.	R″.	Correc.		Queen.	R+r.	Correc.	Average.	Com. A′.	Ratio.
40	P_1	902·	−14·55	887·45	90+s	503·07	−·62	502·71	1	·5664
"	"	"	"	"	90+s	503·6	"		2	
133	"	"	"	"	88+s	522·53	"		1	
"	"	"	"	"	88+s	502·15	"	501·72	2	·5653
40	P_2	902·55	"	888·	17+s	644.3	"		1	
"	"	"	"	"	18+s	644·76	"	643·91	2	·7251
133	"	"	"	"	17+s	643·05	"		1	
"	"	"	"	"	17+s	643·1	"	642·45	2	·7234
40	C	902·4	"	887·85	28+s	1159·6	"		1	
"	"	"	"	"	28+s	1159·1	"	1158·73	2	1·3050
133	"	"	"	"	24+s	1157·0	"		1	
"	"	"	"	"	26+s	1158·8	"	1157·28	2	1·3034
40	C+P_1	902·	"	887·45	105+s	1658·8	"		1	
"	"	902·	"	"	110+s	1664·1	"	1660·77	2	1·8713
133	"	"	"	"	101+s	1656·7	"		1	
"	"	"	"	"	106+s	1660·3	"	1657·96	2	1·8682
40	C+P_2	902·5	"	887·95	10+s	1803·0	"		1	
"	"	"	"	"	12+s	1805·0	"	1803·3	2	2·0261
133	"	"	"	"	8+s	1800·5	"		1	
"	"	"	"	"	8+s	1800·2	"	1799·65	2	2·0221

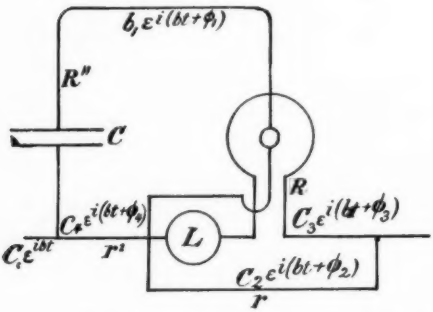
Period.	Coils.	R″.	Correc.		Queen.	R+r.	Correc.	Average.	Com. A′.	Ratio.
40	P_1+P_2+C	902·4	−14·55	887·85	60+s	2306·3	−·62	2307·98	1	2·5995
"	"	"	"	"	?	2310·9	"		2	
133	"	"	"	"	56+s	2304·1	"	2304·13	1	2·5951
"	"	"	"	"	57+s	2305·4	"		2	
40	A	902·43	"	887·88	85+s	4703·	"		1	
"	"	"	"	"	106+s	4724·2	"	4712·98	2	5·3080
133	"	902·4	"	887·85	82+s	4704·2	"		1	
"	"	"	"	"	85+s	4707 0	"	4704·98	2	5·2991
40	A+C−2M	902·35	"	887·8	1146+s	9149·5	"		1	
"	"	"	"	"	1227+s	9233·5	"	9190·88	2	10·3515
133	"	902·4	"	887·85	1170+s	9171·7	"		1	
"	"	"	"	"	1194+s	9191·7	"	9181·08	2	10·3395
40	A+C+2M	902·35	"	887·8	111+s	2550·9	"		1	
"	"	"	"	"	146+s	2556·4	"	2553·03	2	2·8716
133	"	"	"	"	38+s	2548·7	"		1	
"	"	"	"	"	38+s	2548·7	"	2548·08	2	2·8701
40	A+C	902·6	"	888·05	123	5852·	"		1	
"	"	"	"	"	169	5898·	"	5880·13	2	6·6225
133	"	"	"	"	134	5863·5	"		1	
"	"	"	"	"	140	5869·	"	5865·63	2	6·6054

The above results show to what accuracy self-inductances of different values can be compared to each other, or to one of the self-inductances taken as a standard. The reason that the agreement between the different determinations is not greater than it is, even though the electrodynamometer was sensitive to a change of 1 part in 10000 in R+r, is that there was always some little heating of the resistances, and although they were measured in each determination on a Wheatstone bridge, still it was impossible to determine the exact resistance at the time that the experiment was made. This slight effect of the heating of the resistances would not enter in the comparison of two nearly equal self-inductances, that is the comparison of a coil with a standard. The accuracy of this comparison can be made to depend on the accuracy with which R+r can be determined for zero deflection, and this can be done to about 1 part in 10000. To do this, first the standard coil and the coil to be compared are substituted in turn in place of L in figure; they are thus compared separately to a third coil. But as the standard and the coil to be compared are nearly equal in self-inductance, the difference or self-inductance can be determined by the amount necessary to change R+r, and this change will be nearly independent of the slight heating of the resistances. To make a coil of the same self-inductance as the standard, the standard is placed in the R+r circuit and the value of R+r is found that produces no deflection. The coil to be compared is then substituted in place of the standard keeping R+r fixed,

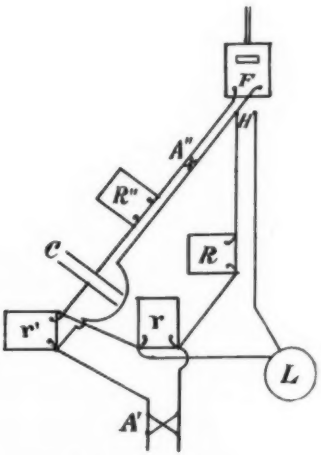
and the self-inductance of this coil is changed until there is no deflection, as in the case of the standard. The accuracy with which this can be done depends on the accuracy with which $R+r$ can be set or 1 part in 10000. This method therefore gives a means of comparing and constructing coils to agree in self-inductance to within 1 part in 10000 with a standard.

Method 6. Zero Method for the comparison of Self-inductance with capacity.

8.



9.



This method resembles Method 12 and the connections are made as in the figures when both the hanging coil and fixed coils of the electrodynamometer are shunted off the main circuit.

Let the currents be denoted by $C_0\varepsilon^{ibt}$, $C_1\varepsilon^{i(bt+\phi_1)}$, $C_2\varepsilon^{i(bt+\phi_2)}$, $C_3\varepsilon^{i(bt+\phi_3)}$, and $C_4\varepsilon^{i(bt+\phi_4)}$. The resistance by R'', r', R and r. The capacity by C. The self-inductance by L. A' and A'' are reversing commutators and F the terminals of the fixed coils and H the terminals of the hanging coil of the electrodynamometer.

If now a periodic electromotive force is applied to the terminals A and B the equations connecting the different currents are as below, from which equations the quantity $C_1C_2\cos(\varphi_1-\varphi_2)$ is to be found, which is proportional to the deflection. From the figure

$$C_4\epsilon^{i(bt+\phi_4)}\, r' = C_1\epsilon^{i(bt+\phi_1)}\left(R'' + \frac{1}{ibc}\right)$$

$$C_4\epsilon^{i(bt-\phi_4)} = C_0\epsilon^{ibt} - C_1\epsilon^{i(bt+\phi_1)}$$

$$\therefore\ C_0\epsilon^{ibt} = C_4\epsilon^{i(bt+\phi_4)}\,\frac{R''+r'+\dfrac{1}{ibc}}{r'}$$

In the same way it is found that

$$C_0\epsilon^{ibt} = C_3\epsilon^{i(bt-\phi_3)}\,\frac{R+r+ibL}{r}$$

$$\therefore\ C_1C_3\epsilon^{i(\phi_4-\phi_3)} = C_3^{\,2}\,\frac{(R+r)r'+ibLr'}{(R''+r')r+\dfrac{r}{ibc}}$$

Therefore the real part is

$$C_1C_3\cos(\phi_4-\phi_3) = C_3^{\,2}\,\frac{(R+r)(R''+r')rr' - \dfrac{L}{c}rr'}{(R''+r')^2r^2+\dfrac{r^2}{b^2c^2}} \propto D$$

where D is the deflection. When D is equal to zero

$$(R+r)(R''+r') - \frac{L}{c} = 0$$

or

$$\frac{L}{c} = (R''+r')(R+r)$$

In the experiments by this method the $\frac{1}{8}$ microfarad Elliott condenser was used, and it was compared with the different coils P_1, P_2, A, and C. The connections were made with open leads and open resistances were used as far as possible, but it was necessary to use resistance boxes for the last adjustments. The connections having been made as in figure, the process of experimenting was to keep r and r' constant and to adjust R'' and R until there was no deflection of the hanging coil. The resistance of the circuits $R'' + r'$ and $R + r$ were then measured on a Wheatstone bridge. The commutator A′ was reversed and the process was repeated. The condenser had absorption (see p. 45) which caused the resistance $R'' + r'$ to be increased by 7·11 ohms. When the capacity is calculated, taking into account the absorption, it is called the corrected capacity, as in the other tables of the paper.

COLLECTED RESULTS.

Coils.	$n=40$. Results found by direct measurement.	Results found by taking sum diff., etc., of separate meas.	Results found by direct meas. of coils and combination of coils.	$n=133$. Results found by taking sum and diff. of separate measurements.
P_1	·5664	·5663	·5653	·5648 $(C+P_1)-C=P_1$
"		·5734		·5730 $(C+P_1+P_2)-(C+P_2)=P_1$
P_2	·7251	·7211	·7233	·7187 $(C+P_2)-C=P_2$
"		·7282		·7269 $(C+P_1+P_2)-(C+P_1)=P_2$
C	1·3050	1·3049	1·3034	1·3029 $(C+P_1)-P_1=C$
"		1·3010		1·2990 $(C+P_2)-P_2=C$
"		1·30.0		1·3065 $(C+P_1+P_2)-P_{1-2}=C$
A	5·3080	5·3175	5·2991	5·3022 $(A+C)-C=A$
P_1+P_2		1·2945		1·2917 $(C+P_1+P_2)-C=P_1+P_2$
"		1·2915		1·2888 P_1+P_2
$C+P_1$	1·8713	1·8714	1·8683	1·8677 $C+P_1$
"		1·8744		1·8718 $(C+P_1+P_2)-P_2=C+P_1$
$C+P_2$	2·0261	2·0331	2·0221	2·0298 $(C+P_1+P_2)-P_1=C+P_2$
$C+P_1+P_2$	2·5995	2·5965	2·5951	2·5920 P_1+P_2+C
$A+C$	6·6225	6·6130	6·6054	6·6025 $A+C=A+C$

In Method 12 connections due to the hanging coil and fixed coils were calculated so that the ratio of the resistances would give the ratio of the self-inductances direct. In this method (6) since the capacity was in circuit with the hanging coil, the self-inductance was so small that it was neglected. The self-inductance of the coils P, etc., which were joined in circuit with the fixed coils, were increased by the self-inductance of the fixed coils, that is by ·0164 henry.

The table below give the various results.

N.	Coil.	Queen in current with $R''+r$.	$R''+r$.	$R+r$.	Product.	Position of A′.	L.	C.	Cor. C.
							·7251		
40	P	2008·	205·	1095 7	2198522·	1	·0164	·3373	
"	"	2005·	200·	"		2	·7415		
133	"	2024·5	221·	"	2218792·	1	·7233		
"	"	2025·5	222·	"		2	·0164	·3330	·3323
							·7397		
40	A	12741 5	30·	1241·85	15922394·	1	5·3080		
"	"	"	30·	"		2	·0164	·3344	
							5·3244		
133	"	12720·	236·	"	15775610·	1	5·2991		
"	"	12716·	220·	"		2	·0164	·3368	·3363
							5·3155		
40	C	3430·8	98·	1140·8	3911004·	1	1·3050		
"	"	3425·8	93·	"		2	·0164	·3379	
							1·3214		

N.	Coil.	R″+r.	Queen in current with R″+r.	R+r.	Product.	Position of A′.	L.	C.	Cor. C.
133	C	3448·8	106+s	1140·8	3933354·	1	1·3034		
"	"	3447·0	105+s	"		2	·0164	·3355	·3346
							1 3198		
40	P	1578·5	57+s	1088·9	1718719·7	1	·5653		
"	"	1578·4	58+s	"		2	·0164	·3384	
							·5817		

This method can be used with great accuracy for the comparison of the capacity of a condenser with a standard condenser. In the comparison, first one condenser and then the other would be placed in the R + r circuit. If the two condensers are of nearly the same capacity, the degree of accuracy of the comparison depends upon the accuracy with which R″ + r′ can be set. The degree of accuracy of setting R″ + r′ varies with the value of the self-inductance with which the condensers are compared. In the experiments just given, using the different coils, the degree of accuracy with which two $\frac{1}{3}$ microfarad condensers could have been compared would vary from 1 part in 2000 to one part in 14000. The two condensers are supposed to be without absorption, as its presence would cause trouble unless the absorption resistances were known.

Résumé.—Summing up the results deduced in this paper, it is seen that the methods for the absolute determination of self-inductance and capacity do not give as concordant results as could be wished. The irregularity of results was caused, in the most part, both in the determination of self-inductance and capacity by the variation of the periods of the currents used in the experiments. As the period enters directly into the determination of self-inductance and capacity, all variations of the period will appear in the results. The determination of capacity is complicated by the presence of electric absorption (pp. 44 and 45). The effect of electric absorption is shown to be that of an added resistance in series with the condenser, called absorption resistance. A direct method is given by which absorption resistance can be measured (p. 41), and experiments are given which show that when condensers possessing absorption are in series or in parallel, their absorption resistances act under these conditions as ohmic resistances in series with the separate condensers (p. 45). Absorption resistance is also found to be extremely sensitive to temperature.

The methods for the comparison of two self-inductances or a self-inductance and a capacity are independent of the period, and when the self-inductances are of different magnitudes the comparison can be made with an accuracy of 1 part in 10000. These methods, therefore, give a means of comparison of a self-inductance with a standard self-inductance, or a capacity with a standard capacity to an accuracy of 1 part in 10000, or they allow the establishment of standards.

Art. VII.—*Reflection of Hertzian Waves at the Ends of Parallel Wires;* by Lee DeForest.

Since the famous experiments of Hertz on electric waves in wires, investigators in this field have found most useful the arrangement known as the Lecher system, or adaptations of this. In its original form this consists essentially of two condensers, each of two metal plates, hung parallel. One pair of these is connected to the secondary terminals of an induction coil, with a spark gap in the circuit. From the other pair of plates lead off two long parallel wires.

By the action of the coil the primary plates are charged with equal and opposite quantities of electricity, which discharge across the gap, when the tension has been raised sufficiently high. Rapid oscillations of a period depending on the capacity of the entire system are thus set up, which induce corresponding impulses in the secondary plates. Electric waves surge over the two wires, to be reflected at their ends with a change in intensity and phase depending on the nature of the terminal arrangement.

Thus standing waves are set up in the wires, which are the better defined, the more nearly the length of the wires approaches an integral number of half wave-lengths.

The ease with which these standing waves can here be measured, and the symmetry and simplicity of the whole arrangement, make this system of the greatest usefulness in all researches where the phenomena of waves in wires are to be studied.

At the nodes of these standing waves, a conducting body, as a wire bridge, may be placed across both wires without interfering with the action beyond.

At an other point, however, such a bridge harms the effect, producing extinction of the glow in a vacuum tube placed across the two wires at their ends.

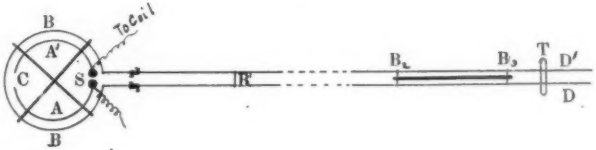
By such means Lecher was enabled to measure readily half wave-lengths, between successive bridges; and inasmuch as theory has shown the velocity of propagation in such a system to be that of light, he could compute the period of the vibration.

With such an apparatus, or with the improved form introduced by Blondlot, an enormous amount of work in determining dielectric constants, indices of reflection, electric dispersion, etc., in fluids, has been accomplished, notably by German physicists. Quantitative experiments have been made with bolometer, electrometer, or thermo-electric means, and thus the attenuation and curves of the standing waves determined.

It was observed that reflection with change of phase occurred at any bridge, bend, or sudden change in the nature of the parallel wires. The mathematical theory for such phenomena has been considerably developed, notably by Drude.*

Theory shows that the waves are reflected at the open ends of the parallel wires without change of sign of electrification. The first node, therefore, would be expected at one quarter of the wave-length from the ends. If capacity of any sort is attached to the ends, however, a change of phase would occur by the reflection and this node be found nearer the ends, by an amount depending on this capacity. Even for bare ends, where no capacity has been assumed, it was early noticed that a change of phase did occur; that the distance to the first node was unexpectedly small.

1.



To investigate this part of the subject was the aim of the experiments described in this paper.

The form of exciter adopted was a compromise between the Lecher and the Blondlot forms. In the latter two pieces of wire, bent semi-circularly, take the place of the primary condenser plates of the Lecher system. To one end of each wire is fastened a small polished zinc ball, forming the spark gap. To the other ends are often attached a pair of metal plates, placed oppositely, to add capacity to the whole.

Outside of the approximate circle thus formed is bent a single wire for the secondary. Its two ends are brought near together, and from these lead out the long parallel wires.

This Blondlot system has a greater damping than the Lecher. Its individual period is less marked, and the frequencies of the waves found upon the parallel wires are almost altogether dependent upon the vibrating systems there formed by bridges arbitrarily located. A great advantage resulting is that a large range of wave-lengths may thus be had from one oscillator.

In the exciter used throughout, instead of wires, two narrow zinc plates, A A′, each 15^{cm} long, $1{\cdot}5^{cm}$ wide in the middle, and *elliptical* in shape, formed the primary. These were bent as shown in Fig. 1, and each carried a zinc ball, 8^{mm} in diameter,

* Wied. Ann., lii, p. 499; liii, p. 751.

centered at a focus of the ellipse together with the leading-in wires. Thus reflections from every part of the edges of the plates were concentrated simultaneously at the gap.

The spark gap between these two balls varied from 1^{mm} to 2^{mm}. About this primary oscillator a similar zinc strip 32^{cm} long was bent to form the secondary. The whole was immersed in a glass vessel containing kerosene oil. But $0{\cdot}5^{cm}$ separated the primary from secondary, and without the oil violent spark discharges passed between all parts of the system. The petroleum was decomposed by the electrical action, carbon being deposited upon the zincs. This oil was renewed from time to time.

This particular arrangement combines advantages of both the Lecher and Blondlot exciters. By the use of plates all the elements of the primary and secondary may be brought closer, the loss of energy found in the Lecher exciter obviated; and the uninterrupted form of the secondary connects the two parallel wires as in the Blondlot, allowing perfect reflection or interchanging of the back-coming waves from DD′. Moreover, the damping of this oscillator was such that its individual period had little effect upon the resonator system of the wires. I could by judicious bridging get almost any wave-length from 50^{cm} to 3 meters. The case was analogous to that of any acoustic vibrating system when struck by a body of any period whatsoever—the primary oscillation caused by the spark discharge serving merely to excite surgings in D B D′, the period of which is determined by the location of the first bridge on DD′.

When the length of the wires DD′ is properly proportioned to the period of the exciter, we have of course the strongest possible action. With a first bridge at 36^{cm} from S, and succeeding ones 43–44^{cm} apart, the vacuum tube, laid across the ends of the wires to serve as a detector, was found to glow with eight bridges on the wires.

For any other wave-length so great a number of bridges quite extinguished the effect of the primary vibrations. I regarded then 86–88^{cm} as the primary wave-length; the natural period, calculated,* is 60^{cm} in oil, giving $86{\cdot}4^{cm}$ in air.

A certain dim glow persisted in the tube, no matter how many bridges were on the wires or where placed. This was found due to the oscillations of the coil, of enormous wave-length, and relatively gradual, unreflected by any form of bridge used, whereas the shorter ones due to the sudden oscillations across S are cut off very sharply. With practice there was no difficulty in distinguishing the different characters of the glow produced by these Hertzian oscillations.

To allow of work in daylight this vacuum tube was completely enclosed in a light-tight box, and viewed through a slot and

* By Drude's method, Wied. Ann., lv, p. 634.

eye-shade. Then by means of an endless cord passed through two pulleys and running below the wires, the observer stationed at the tube could slide a bridge, attached to the cord by wooden clamps, along the wires.

When a node was located by this means, the place was marked, a new bridge hung there, and the sliding bridge then moved farther along the wires. On each bridge was hung a wooden block to hold it fixed in place and in good contact. To facilitate measurements a long scale-piece, graduated in half-centimeters, was below the wires, and the intervals between bridges read therefrom by means of a sliding index arm.

For the purposes intended the vacuum tube was the best indicator known, though but roughly quantitative. To reduce the deforming effect on the standing waves from its capacity to a minimum, no electrode nor tinfoil was used, the bare tube being laid across the parallel wires. Even then it possessed a capacity, as found by a long series of measurements, equivalent to a length of 4^{cm} of the line. This was independent of the wave-lengths used, and was thereafter allowed for in all measurements of wave-lengths where the tube was present.

Relation between Change of Phase in Reflection from Open Ends, and the Frequency.

When an electric wave passes along a conductor we have at any point this relation between the E. M. F. and current:

$$-\frac{d\phi}{dx} - L\frac{dC}{dt} = RC$$

where ϕ = Electro-static potential
C = Current
R = Resistance of the circuit per cm.
L = Self-induction " " "
Let S = Elect. static capacity "
Q = Quantity of electricity per unit length.

Then $C = Q\frac{dx}{dt} = Qv$ where v = the velocity of propagation.

$$\therefore C = S\phi v$$

$$\therefore \frac{d\phi}{dx} + LSv\frac{d\phi}{dt} + VRS\phi = 0$$

When and where $\phi = 0$ we have*

$$\frac{\delta\phi}{\delta x} + LS\frac{\delta\phi}{\delta t} = 0 \qquad (1)$$

* Barton, Proc. Royal Soc., vol. liv, p. 87.

$$\text{or} \quad \frac{\delta\phi}{\delta t}\frac{\delta t}{\delta x} + \text{VLS}\frac{\delta\phi}{\delta t} = 0$$

$$\therefore \frac{\delta\phi}{\delta t}\left[vLS - \frac{1}{v}\right] = 0$$

whence $v = \frac{1}{\sqrt{LS}}$ or $Lv = \frac{1}{Sv}$, the well-known Thomson formula for the velocity of the propagation of the wave.

Now the capacity per unit length of the normal part of the Lecher parallel wires is given* very closely by the form

$$S = \frac{1}{4 \text{ Log nat } \frac{d}{r}}$$

in electro-static units, where r = radius of the wires, d their distance apart.

In the wires used $r = \cdot 37^{mm}$; $d = 1 \cdot 7^{cm}$. Also $L = 4$ Log nat $\frac{d}{r}$ in electro-magnetic units. Thus the period of Lecher's system, as well as for circular or rectangular resonators, is independent of r or d. And if the resistance is negligible compared to $2vL$ (which is the case for wires greater than $0 \cdot 5^{mm}$ diameter or thereabouts, and less than 100^{m} long), the velocity of propagation thereon is that of light. Especially at the point of reflection the resistance R may be neglected. Equation (1) becomes

$$v\frac{\delta\phi}{d\gamma} + \frac{\delta\phi}{dt} \qquad \text{and its solution:}$$

$$\phi = f_1(nt - \beta_0 x) + f_2(nt + \beta_0 x)$$

where $\frac{n}{\beta_0} = v = \frac{1}{\sqrt{LS}}$ and f_1; f_2 denote any functions (in our case sine functions) with coefficients for the various amplitudes, and a third term in the parentheses to allow for change of phase. So for the original and reflected waves, where $x = 0$ write:

$$V_1 = \phi \sin\left(nt - \frac{\delta_1}{2}\right) \qquad (2)$$

$$V_2 = \phi' \sin\left(nt + \frac{\delta_1}{2}\right)$$

where δ_1 is the angle of change of phase in reflection.

*e. g. Lord Rayleigh, Phil. Mag., August, 1897.

But we must consider the case of a condenser, of capacity S_1 between the ends of the two parallel wires. Then if V denote the resultant potential-difference in the wires at the ends from incident and reflected waves, and C the resultant current, we have the condenser equation

$$\frac{\delta V}{dt} = \frac{C}{S_1}$$ if there is no transmitted

wave; and b, the coefficient of reflection, equals 1.

But in the case of open ends we must suppose a part of the energy radiated off, either in expanding, approximately spherical, waves, or for a distance as a beam, more or less plane polarized. The amount lost will be greater the less the capacity of the end condenser.

But for our purpose it is unnecessary to determine the exact course or nature of the wave after leaving the wires. We may consider the case as though the wires were continued past the end condenser, by a pair having a different capacity S_2 per unit length.

Let e_1 be the charge on unit length of the wires due to the incident wave; and e_2 the charge per unit length carried off, with the same velocity v.

Then we may write:

$$C_2 = e_2 v = c e_1 v = g e,$$

where c = coefficient of transmission, and $g = cv$.

Now $$e_1 = \frac{C_1}{v} \text{ and } C_1 = \frac{V_1}{Lv}$$

$$\therefore C_2 = cC_1 = cV_1 S v$$

Corresponding to the condenser equation we now have

$$\frac{dV}{dt} = \frac{C_{12} + C_2}{S_1} = \frac{C}{S_1} + \frac{cV_1}{S_1 Lv}$$

Let $\gamma = \frac{S_1}{S}$, the ratio between the capacities of the end condenser and that of a unit length of the line.

$$\therefore \frac{dV}{dt} = \frac{C}{S_1} + \frac{gV_1}{\gamma}; \quad V = V_1 + V_2 \qquad (3)$$

Substituting in this the values given for C and V_1, and developing the equation, we get, letting $t = 0$,

$$n(\phi + \phi') \cos \frac{\delta_1}{2} = - \frac{\phi\left(1 + \frac{g}{\gamma} S_1 Lv\right) + \phi'}{S_1 Lv} \sin \frac{\delta_1}{2} \qquad (4)$$

Letting $nt = \frac{\pi}{2}$,

$$n(\phi - \phi') \sin \frac{\delta_1}{2} = \frac{\left(1 + \frac{g}{\gamma} S_1 L v\right)\phi - \phi'}{S_1 L v} \cos \frac{\delta_1}{2}, \text{ where } \phi' = b\phi \quad (5)$$

We find that the angle of phase difference may be considered as in the second quadrant, the cosines having negative signs. So here if we write the cosine of eq. (4) = − cos. of (5), and at same time make the coefficient of reflection b of (4) equal $-b$ of (5), we can solve between the two equations.

Hence

$$\tan \delta_1 = \frac{-2 L v S_1 n K}{1 - (L v S_1 n K)^2} = \frac{2 K \gamma \lambda}{K^2 \gamma^2 - \lambda^2} \quad (6)$$

Where $K = \dfrac{1 + b}{1 + b + \frac{g}{\gamma} S_1 L v}$

From (6) we get,

$$S_1 = \lambda \frac{S}{K} \left(\frac{\cos \delta_1 + 1}{\sin \delta_1} \right) \quad (7)$$

From this equation the capacity of the terminal arrangement can be calculated from the observed values of S_1 and the wave length λ used.

For λ large compared to γ (as was the case for the wave-lengths used) K is nearly unity for $b = 1$, and for b as small as 0·7, $K = \frac{17}{14}$ only. K is taken as unity throughout.

The value of $S = \frac{1}{L}$ calculated for the parallel wires is ·067 C. G. S. units. For these wires and frequencies any correction terms for S or L, as by Rayleigh's or Heaviside's formulæ, are absolutely negligible, although the resistances for these oscillations are not at all the same as for steady currents.

Formula (7) was applied to the determination of end capacities for the wire ends bare, and again carrying two brass balls, and under varying conditions, for wave-lengths ranging from 60 to 170 centimeters.

The indicator tube was placed across the wires, generally in the second loop from the ends, sometimes in the last (one-quarter wave-length). In the latter position 8^{cm} were allowed for its presence. No bridge could be placed between the tube and the ends in either case, because it was found that the oscillation of any "system" between two successive bridges, was not perceptibly affected by the resonance or non-resonance of

any system *behind* it, but only by those between it and the source.

The half wave-length was fixed by two bridges, at the desired distance apart, attached to a strip of wood and always moved together back and forth along the line. The nodes thus located were naturally broader and less defined than when but one bridge was shifted.

Although the whole range of half wave-lengths was attempted, at intervals of $2{\cdot}5^{cm}$, only a few could be satisfactorily observed. This was due to the necessity for a *double* resonance to secure a glow in the tube. The system defined by the two bridges kept one half wave-length apart must be in resonance both with the end system and with the part in front including the exciter.

Had it been feasible to employ much longer wires, 100^{m}, this necessity would not have existed with the limited wave-trains sent out by the exciter.

Regarding the bare ends as two spheres of the radius of the wires, the static capacity as calculated graphically by the methods of inverse points was found to be

$$S_1 = {\cdot}45 \text{ C. G. S.}$$

Thus the actual capacity for the bare ends, for these rapid oscillations, is seen to be very much greater than that calculated for static charges, and varies with the frequency. The curves in Fig. 2 show a slight decrease in the change of phase by reflection with increasing frequency, and a more marked falling off in the end capacity. This decrease in capacity with period is to be expected.

With two brass balls on the ends, $1{\cdot}85^{cm}$ diam., $2{\cdot}55^{cm}$ between centers, the lost length in reflection is of course much more marked. The extreme limits of the balls were here taken as marking the end of the wires.

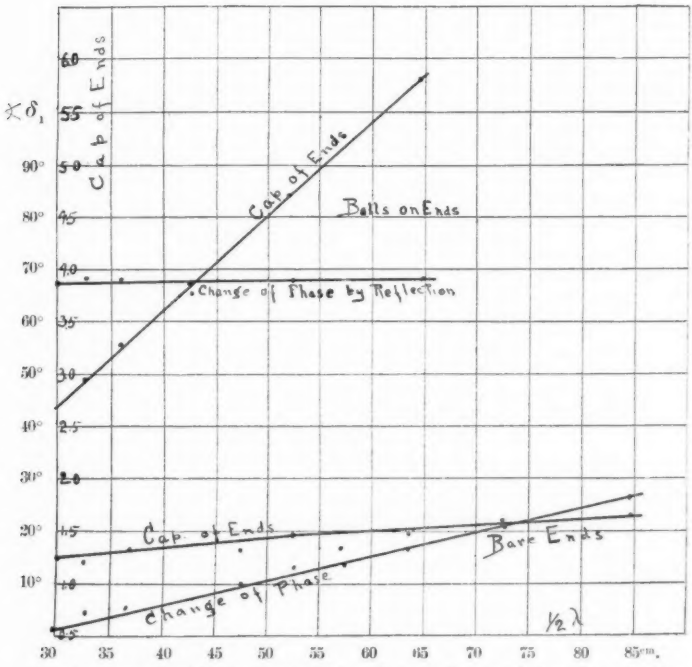
The reflection throughout seemed much better for these balls at ends than for bare ends; the nodes were always more easily located and clearly defined. There was no difference in the character of the reflection with the bare ends, whether these were cut off square or tapered to fine points.

By Maxwell's method the calculated static capacity of the balls is 1·15 C. G. S. units. The observed capacities for these oscillations are from 2 to 5 times greater than this—a much smaller discrepancy than for the case of bare ends. The radiation from the balls is much less.

In the curves given the figures for amounts lost in reflection cannot be defined closer than $\pm 0{\cdot}5^{cm}$, because of the broad nodes found, allowing an error of from 2 to 4 per cent in the angles of change of phase.

As to the reflection from rectangular bends in the wires :—so long as the two wires were kept parallel, there was no precep-

2.



Abscissas represent half wave-lengths, ordinates change of phase by reflection, and capacity of ends.

tible difference or change in the angle of phase. Such corners did not therefore affect to any observable extent the capacities of the end systems, for any frequencies used.

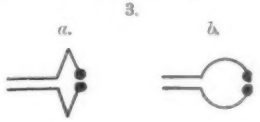
But when the wires were bent out *from* each other the clearness of node was very much impaired—the greater the angle the less sharp the definition—due to the double reflection then existing.

If the distance between the ends, bare or with balls attached, is kept fixed and a certain section of the wires next adjoining is bent or bowed *out*, from straight and parallel wires into curved or circular forms, the last quarter wave-length is observed to shorten, then increase again. The capacity of the section is changed, until when at last the wires are bent out and back, as in (*a*), Fig. 3, the capacity may be less than for the

original parallel wires; passing through a maximum when the *circular* form (*b*) is taken.

In this case the area also is a maximum.

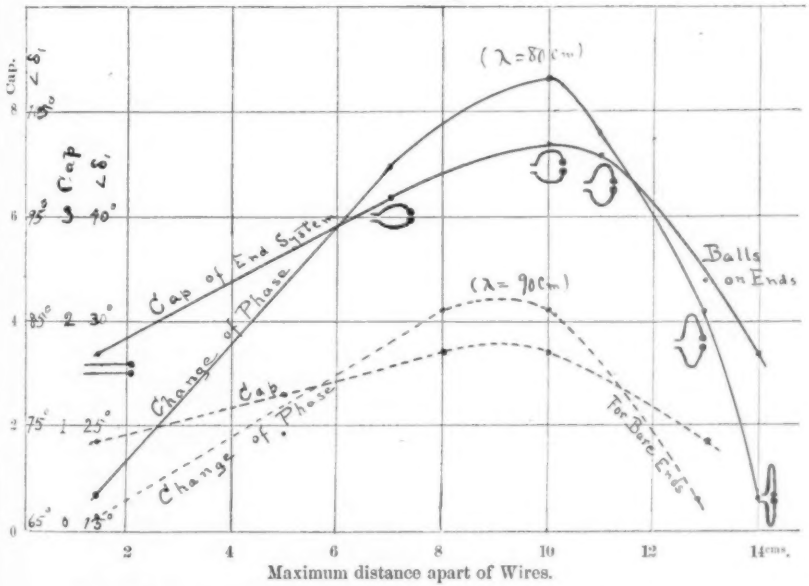
3.



The same phenomenon was observed for bare ends as for the two balls, though again less pronounced; for a longer section of the wires thus bent the effect is still more marked.

In fig. 4 is shown this relation between the form of the ends and the change in capacity and phase.

4.



Maximum distance apart of Wires.

Now when such convex bends are put into the parallel wires distant from their ends, the effect is the reverse. Von Geitel* found that they produced a decrease in the capacity of the wires at the point, (as is to be expected from the expressions for the capacity), causing a reflection of the same sign as would a change in wires from thick to thin. By bending the wires in he obtained the opposite reflection. So here it is evidently connected with the terminals. The change of phase is maximum when the ends are close together and still as far removed as possible from the influence of the leading-in wires.

* Wied. Ann., xlix, p. 184.

A peculiarity noticed in the action of the tube was its sluggishness in responding to the waves, it seeming to require at first a strong excitation to enable it to respond to weaker. At the start all bridges were removed before a glow would result. The gas seemed to require a "warming up"—its particles violently excited electrically—before weaker discharges passed.

It was noticed also that if the hand was placed on the wires anywhere, even behind the tube, all glow ceased. The same occurred if the wires were grounded, or a very large capacity attached. Yet here the tube was subjected at least to the incident wave, and theoretically, since a large capacity on both wires is like a no-resistance bridge, there should be also perfect reflection and standing waves. But the action is as though due to free electricity on the wires. Grounding at any point keeps its potential zero, and a heaping-up of the charges on the wires is impossible. With the electrometer also, no deflection was possible so long as a large capacity was attached to the parallel wires.

The electrometer used carried, suspended by a glass fiber 25^{cm} long, a needle consisting of two small aluminum disks, moving in the horizontal plane. Parallel to, and a few millimeters above each end of this needle, was fixed a similar disk, connected by fine wire to one of the parallel wires. The whole was suspended in a vessel of albolene oil. This liquid answered admirably, affording the right damping quality and dielectric strength.

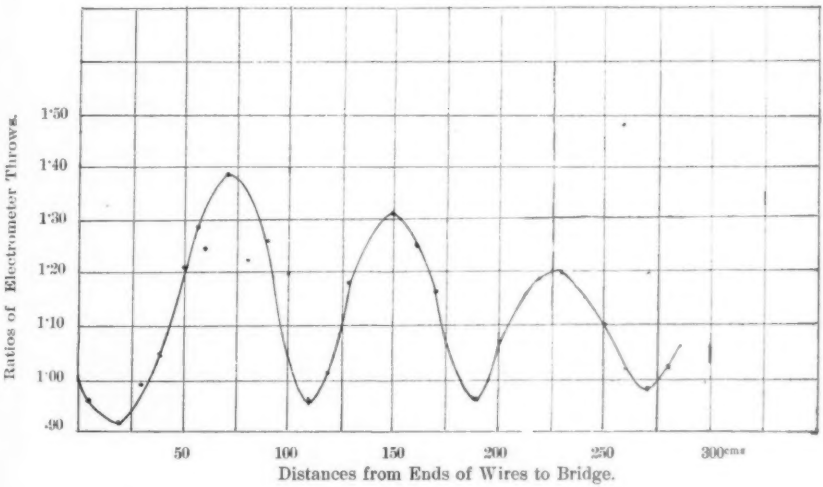
From the center of the needle a fine platinum wire dipped into a small cup of mercury, connected by wire to some capacity. It was found that the deflection was much increased by this, being maximum when the needle was grounded. The sensitiveness of the instrument could thus be directly regulated, and when this leading-out wire was insulated the deflection of the needle charged by induction was almost nothing.

A mirror and scale were unnecessary. A light index arm of glass, 8 inches long, was attached to the upper end of the wooden axis of the needle, where the same joined the glass suspension fiber, above the surface of the oil. This index moved over the face of a mirror scale carrying 120 divisions. The zero was very constant.

For its best working the electrometer did not require the amount of energy in the spark discharge that the glow-tube demanded. The zinc ball gap was made very short, as well as the auxiliary spark gap between the coil and exciter; and the spring interrupter of the coil was adjusted to give as nearly as possible a continuous passage of sparks. The surfaces of this break were kept constantly smooth, as the slightest falling-off of the interrupter, even though unnoticeable to the ear, was at once evidenced by failure of the high-frequency waves.

The decrement of amplitudes in each train of waves here sent out is found to be such that the standing waves created decrease rapidly with increasing distances from the reflecting body. This decrement completely over-masks, in copper wires, that due to attenuation along the wires, for the lengths considered.

5.



This electrometer gave the accompanying curve, fig. 5, similar to those observed by Bjerknes, Barton, and others. As it was impracticable to move the electrometer along the wires the following method was used:—Wires 9·6 meters long were employed and the instrument stationed 4·5 meters from the end. One no-resistance bridge was placed across the wires at a point three-fourths of a natural wave-length beyond the electrometer. This was alternately raised and lowered, so that reflection alternately occurred from it and from a similar bridge moved along the line towards the ends.

The action of the coil is at best so irregular that measurements must be made as nearly simultaneously as possible. First throws of the electrometer needle were read, as much more satisfactory and regular than mean deflections. From 30 to 40 *good* alternate readings were taken for each position of the sliding bridge; the mean ratios of the swings for the two bridges give the relative amplitudes of the two waves. These ratios are plotted as ordinates, and the distances of the sliding bridge from the electrometer as abscissæ. As the distance

between the two bridges decreases the discrepancies between throws are seen to diminish, approaching zero. The effective length of the wave-train is about 8 meters.

From this curve the exponential decrement of amplitudes is found to be $x = \cdot00095$ per cm.

Experiments with the Coherer.

A coherer was used in looking for polarization in the field near the wires. A glass tube half filled with coarse copper filings was placed in the nose of a large zinc funnel, soldered into the side of a tin box. The galvanometer, dry cell, and a graphite resistance of some 150,000 ohms, were shielded in this, leaving only a small aperture through which to read the mirror. Thus protected the coherer responded only to the waves from the parallel wires placed near.

Three gratings were tried: one made of half-inch strips of zinc, alternating with paper; the second, of lengths of insulated copper wire 3^{mm} in diameter, placed as closely as possible; the third, of wires $0{\cdot}6^{mm}$ diameter, strung 5^{mm} apart.

Along the length of the Lecher wires absolutely no polarized displacements were found, whether the coherer lay in the plane of the two parallel wires, or in one perpendicular to this and equally distant from both wires—and whether the coherer were close to or far from these. The waves are propagated in approximately circular forms from the wires, with displacements tangentially perpendicular to them; but there are also displacements parallel to the wires from the flow of the currents in them. One at least of these two components will always penetrate the grating.

That the displacements are not radial here is shown by the complete shielding from them afforded by a tin pipe, as large as 3 inches in diameter, fitted on to the end of the funnel. If this extended more than three inches the action was entirely cut off. This amount of protection was necessary, however, to shield the coherer from diffuse radiation.

The coherer was next placed beyond and facing the ends of the parallel wires (8^{cm} apart). Here also at a distance greater than 15^{cm} from the ends the waves were not polarized, and were cut off as before by a long projecting tin cap. When, however, the ends were brought up close to the grating, or about 8^{cm} from the coherer, a very decided polarization was found. The plane of the two wires being horizontal, the galvanometer gave deflections averaging 17 for the grating strips vertical, and none whatever for them horizontal. This was with the first-mentioned analyzer. The second gave average deflections corresponding to 16 and 2 respectively for the two positions;

the third, deflections 23 to 6 respectively. Rotating the first analyzer, the average results shown in the following table were obtained.

Angle of strips from vertical.	Deflection.	Equivalent deflection.	Cosine of angle.
0·	26	1·0	1·0
22·5°	18	·7	·9
45·0	9	·35	·7
67·5	4	·16	·4
90·0	0	·0	·0

Using two gratings, the segments of the one nearest the coherer lying horizontal, and those of the one in front at an angle of 45° to these, an occasional deflection was secured. More often, however, the resolved vertical component from the first was too weak to penetrate the second. With both gratings vertical good deflections were secured.

Thus the earlier assumption that a beam, as it were, of plane-polarized displacement traveled on beyond the ends of the two wires, was justified. It is also shown very strikingly that it is the component *perpendicular* to the elements of the grating that passes through it. At a very little distance from the ends this plane-polarized beam is lost in the expanding (spherical) waves, or in those diffusely reflected.

Very much might be determined as to the exact nature of the field in the neighborhood of the wires by such use of the coherer—devising proper shields, analyzers, resonators, etc., although as now used it is only roughly quantitative.

My best thanks are due Professor Wright, for the facilities of the Sloane Laboratory put at my disposal, and for kindly interest and valuable suggestions throughout the course of this work, and to Prof. Gibbs for helpful advice.

Sloane Physical Laboratory,
Yale University, May 31, 1899.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Peroxides.*—Some further results have been published by Melikoff and Pissarjewsky in their investigations on peroxides. They have shown that acid peroxides may form salts with alkali peroxides. The resulting soluble salts, such for example as the sodium and lithium salts of peruranic acids, when treated with aluminum hydrate are converted into the free acid and hydrogen peroxide. The insoluble salts, such as the barium salt of peruranic acid, when treated with carbon dioxide, act like barium peroxide; barium carbonate, hydrogen peroxide, and peruranic acid being formed. Acid peroxides RO_4 have been obtained from elements belonging to six groups. The stability of the salts formed by them with alkali peroxides decreases with the atomic mass of the element forming the acid peroxide. With metallic peroxides, strongly acid peroxides do not form salts but decompose them, forming hydrogen peroxide. They assign to the peroxy-acids and the metallic peroxides the constitution HO—OH analogous to that of hydrogen peroxide, as they behave similarly with certain reagents. They yield hydrogen peroxide on treatment with dilute sulphuric acid, but if the acid is concentrated many of them yield ozone. Water decomposes the peroxy-acids as it does the peroxides; sodium perborate for example being partially decomposed into sodium metaborate and hydrogen peroxide. The peroxy-acids also behave like the metallic peroxides when treated with manganese peroxide, oxygen being evolved rapidly in the case of soluble salts and slowly in the case of insoluble ones; the peroxy-acids oxidize alkalis, easily converting them into peroxides.—*Zeitschr. Anorg. Chem.*, xviii, 59–65, 1898.

G. F. B.

2. *On the Preparation of Iron Silicide.*—The fact has been observed by Lebeau that copper silicide in the melted state dissolves iron silicide very readily. And upon this he has based a method of preparing the latter compound. Commercial copper silicide, coarsely pulverized, is mixed with ten per cent of iron filings, the mixture is placed in a carbon crucible and this is inserted in an electric furnace supplied with a current of 950 amperes at a pressure of 45 volts, for from four to five minutes. A button is thus obtained, white in color and having a crystalline fracture. It is coarsely pulverized and treated with diluted nitric acid, the temperature being raised toward the end. The copper silicide is dissolved and crystals of iron silicide remain surrounded by gelatinous silica. To remove this, the crystals after washing are heated with a solution of caustic soda. Repetition of the treatment with nitric acid and with soda gives the iron silicide pure. It has the composition SiFe, thus differing from the silicide $SiFe_2$ prepared by Moissan by the direct union

of iron and silicium in the electric furnace. It is in the form of tetrahedral crystals having a density of 6·17 at 15°. They scratch quartz but not corundum. Iron silicide is not attacked by oxygen or hydrogen at a red heat, but chlorine, bromine and fluorine act upon it at a red heat with incandescence. Mineral acids are without action upon it, but fused alkalis, or a mixture of fused nitrate and carbonate, attack it readily.—*C. R.*, cxxviii, 933–936, April, 1899. G. F. B.

3. *On an Application of the Equilibrium Law to the Formation of Oceanic Salt Deposits.*—An investigation has been undertaken by VAN'T HOFF AND MEYERHOFFER for the purpose of determining theoretically from the law of equilibrium the order of deposition of salts in consequence of the evaporation of sea water, with especial reference to the Stassfurt beds. Evidently, the relations of the individual salts present to each other have to be first considered, and the present paper considers the solubility curves of the various hydrates of magnesium chloride at temperatures varying from −33·6° to +186°, the point when hydrogen chloride begins to be evolved. The complete equilibrium curve for magnesium chloride and water may be divided into the following portions: (1) Stable solution in equilibrium with ice, from 0° to −33·6°; (2) Stable solutions in equilibrium with the following hydrates, $MgCl_2.(H_2O)_{12}$ from −33·6° to −16·8°; $MgCl_2.(H_2O)_8$ from −16.8° to −3·4°; $MgCl_2(H_2O)_6$ from −3·4° to 116·67°; $MgCl_2.(H_2O)_4$ from 116·67 to 181°; $MgCl_2.(H_2O)_2$ above 181° or 182°; (3) labile solution in equilibrium with $MgCl_2.(H_2O)_2(\beta)$ from −17·4° to −9·6°. Labile continuations of the curves for the hexahydrate and the dodecahydrate can be obtained, meeting at −30°, whilst similar continuations of the ice and octahydrate equilibrium curves cut at −50°. The dodecahydrate was previously unknown and is best produced by cooling a solution containing a little more water than is required for the crystals, to about −20° and then inducing local over-cooling by solid carbon dioxide. The stable and labile octahydrates also previously unknown can be produced in a similar manner by cooling a solution of the composition $MgCl_2.(H_2O)_{11}$. Once formed, the labile hydrate might remain unchanged for a whole day, but its production could not be depended on. The values found for the solubility of the hexahydrate were in general slightly lower than those of other observers, probably owing to more complete freedom from calcium chloride.—*Zeitschr. physikal. Chem.*, xxvii, 75–93; *J. Chem. Soc.*, lxxiv, 564, December, 1898. G. F. B.

4. *The Spirit of Organic Chemistry, an Introduction to the Current Literature of the Subject;* by ARTHUR LACHMAN. 12mo, pp. xviii + 229. New York (The Macmillan Company).—This book, which is intended primarily as a supplement to text-books of organic chemistry, consists of nine excellent essays upon the development of some of the most important problems of the science. The subjects dealt with are, the constitution of rosani-

line, Perkins reaction, the constitution of benzene, the constitution of acetoacetic ether, the uric acid group, the constitution of the sugars, the isomerism of maleïc and fumaric acids, the isomerism of the oximes, and the constitution of the diazo compounds. The work will be useful as a source of information regarding the history and present status of these particular topics, and it will be valuable also in giving the student a clear idea of the objects of chemical research, and arousing his interest in the literature.

H. L. W.

5. *Lehrbuch der Allgemeinen Chemie.* Von Dr. WILH. OSTWALD. Zweiten Bandes, Zweiter Teil: Verwandtschaftslehre. Vierte Lieferung: Bogen 39–52 Mit Figen 71–152. Zweite umgearbeitete Auflage. Leipzig, 1899 (Wm. Engelmann).— Some of the earlier parts of this fundamentally important work have been already noticed in this Journal, and those interested are well acquainted with its scope and value. The present Fourth Part (pp. 625–828) discusses the cases of Chemical Equilibrium of the Second Order. The part following is to contain those of the Equilibrium of the Third and Higher Orders, and with this the second part of the second volume will be brought to a close.

6. *Insulators for Heat.*—Walter Hempel has made a comparison of the relative value of different media for heat insulation, and gives the following table:

Temperatures in the interior of the vessels.

	Duration of time in minutes						
	5	32	58	88	115	160	207
Dry, clean sheep's wool (dried at 100°)	−74	−63	−61	−50			
Cotton wool	−76	−63	−56	−43			
Silk	−76	−65	−58	−48			
Moist sheep's wool	−76	−64	−54	−44			
Clean wool, air dried	−77	−74	−64	−55			
Eider down	−78	−76	−67	−66	−49	−33	−17
Vacuum tubes of D. Bender and D. Holbein I	−66	−67	−49	−32	−8	+2	+8
Vacuum tubes of D. Bender and D. Holbein II	−68	−65	−49	−34	−11	+1	+8
Weinhold-Dewar tubes— Silvered	−78	−77	−74	−70	−64	−59	−50

It thus appears that carefully exhausted vessels give a better means of heat insulation than any other means, while partially exhausted vessels are inferior to the other means in the above list.— *Wied. Ann.*, No. 5, 1899, pp. 135–138. J. T.

7. *Optical relations of Gold and Platinum layers.*—This is an examination of the work of various investigators and a study of the best method of making the measures. The author, G. BREITHAUPT, finds that a method by Schmidt permits of the measure of the index of refraction of metals. Gold gives the most constant values, while platinum does not give consistent ones. Mirrors of obsidian proved of value as foundations for the layers. Burned-

in gold showed normal dispersion, while burned-in platinum exhibited anomalous dispersion. Steel and nickel-steel showed anomalous dispersion; brass, highly polished, normal dispersion.— *Wied. Ann.*, No. 5, 1899, pp. 46–73. J. T.

8. *Electrical Waves.*—ALBERT NEUGSCHWENDER has described a new method of detecting electric waves, which consists in using as receiver two pieces of tin foil separated by a fine line. This Rhigi resonator is placed in one branch of a Wheatstone bridge. The fine line is moistened by various electrolytes or by vapors. When the electric waves impinge on the slit its resistance is greatly increased, in some cases rising from 80 to 90,000 ohms. The author has carefully investigated the phenomena, and finds that the waves disturb the formation of fine filaments of metal in the electrolytes (Metallbäumchen), which are essential for good conductivity.— *Wied. Ann.*, No. 5, 1899, pp. 92–98. J. T.

9. *Ether Movements.*—G. MIL discusses analytically the question of the fixed and moving ether in relation to Poynting's hypothesis. In order to ascertain a possible limit, he arranged condensers in a powerful magnetic field in such manner that the electrostatic lines of force were at right angles to the magnetic lines, and by means of an interferential refractometer tested whether a light ray suffered any change in velocity. A negative result was obtained. This, according to the author, does not show that the ether is fixed, although the value for μ (inertia of ether particles) was $\mu > 10^{-10}$, which is very small.— *Wied. Ann.*, No. 5, 1899, pp. 129–134. J. T.

10. *Verhandlungen der Deutschen Physikalischen Gesellschaft.* —Physicists will be interested in the announcement recently made by the publishing house of Johann Ambrosius Barth, in Leipzig, that it is proposed to publish the Transactions of the German Physical Society, successor to the Physical Society of Berlin, in successive numbers, published as called for, and for which an annual subscription price of 4 marks will be charged. The first number (pp. 1–48) has already been issued.

II. GEOLOGY AND MINERALOGY.

1. *United States Geological Survey, Eighteenth Annual Report*, 1896–97.—The bound volumes of the Eighteenth Annual Report have been issued in five volumes. Part I, *Director's Report*, including *Triangulation and spirit leveling*, pp. 440. Part II, *Papers chiefly of a theoretic nature*, pp. 653. Part III, *Economic geology*, pp. 861. Part IV, *Hydrography*, pp. 756. Part V, *Mineral resources of U. S. for* 1896. Each of the volumes is illustrated by numerous plates and maps. The contents of the second volume have in part been already noticed in this Journal, as they were issued in pamphlet form. Special notice at this time should be drawn, however, to a few not heretofore mentioned:

The Triassic formation of Connecticut, pp. 1–192, plates 1–20; by W. M. DAVIS.—This is the final report of Professor Davis on the Triassic area, which he has been studying for a number of years, the main facts and theories of which have already become well known to geologists. The final volume is beautifully illustrated, and is particularly valuable for the photographic representations of several contacts between the trap and the sedimentary rocks, and the clear, systematic presentation of the whole subject.

Glaciers of Mt. Rainier, with a paper by G. O. SMITH *on the rocks of Mt. Rainier*, pp. 349–423, plates lxv–lxxxii; by I. C. RUSSELL.—This is a beautifully illustrated account of a glaciated mountain region in Washington, which presents some remarkable features that should attract visitors and sight-seers, as well as the professional geologists.

Geology of Cape Cod District, pp. 497–593, plates xcvii–civ; by N. S. SHALER.—In this paper Professor Shaler gives, in a graphic manner, an account of the superficial geological structure of the district about Cape Cod, tracing the features back to their supposed causes, viz: glaciation, erosion, etc.

Recent earth movement in the Great Lakes Region, pp. 595–653, plate cv; by G. K. GILBERT.—Mr. Gilbert elaborates some of the later results of his studies of the earth movements as affecting the Lake Regions. He has shown the methods of recording observations, and given comparisons of movements in relation to Lake levels, and has drawn together the various observations and reduced them to a form expressing differential movements of the whole region, estimating the rate and direction of past and present movements. (See this Journal, March, 1899, p. 239.)

In the volume of *Economic Geology* are several very valuable reports. The first two, on the Gold fields of Alaska, respectively by Messrs. Becker, and Spurr and Goodrich, have already been noticed in these pages.

Four other important papers are given: Some Coal fields of Puget Sound, pp. 393–436, plates lii–lxviii, by B. Willis; Geology and mineral resources of the Judith Mountains of Montana, pp. 437–616, plates lxix–lxxxvi, by Messrs. W. H. Weed and L. V. Pirsson; The mining districts of the Idaho Basin and the Boise Range, Idaho, by Waldemar Lindgren; with a report on the fossil plants of the Payette formation, by F. H. Knowlton, pp. 617–744, plates lxxxvii–cii; Preliminary report on the mining industries of the Telluride quadrangle, Colorado, pp. 745–850, plates ciii–cxviii, by C. W. Purrington. W.

2. *Nineteenth Annual Report of the Director of the United States Geological Survey*, 1897–98, CHARLES D. WALCOTT, Director, pp. 1–143, plates i–ii.—The Director's report of operations for the year 1897–98, and contents of the final report, is in hand. The operations of the Survey are a continuation of those of last year, with very slight modification in general. We note a few important results in the course of the report, reported by the

several members of the Survey. The aggregate appropriation for the Geological Survey for this year was a little over one million dollars.

In Mr. Emmons's report on work in the Rocky Mountain Region, the following results regarding the Tintic mining region of Utah are reported:

"Contrary to what is usually the case in Western mining districts, there appears to have been no genetic connection between ore deposition and eruptive action, for it has been proved that the most important ore bodies—viz., those entirely inclosed in sedimentary rocks—were formed and eroded before the igneous rocks were erupted."

"The complete independence of the ground-water level in the mine in sedimentary and those in igneous rocks."

"As a consequence of the depth of the permanent water level in the former mines, their ores have been very largely oxidized, and in this process of oxidation there has been a remarkable separation of the minerals according to their metallic bases, lead ores predominating at one point, copper ores at another, and silver ores at a third."

Mr. Lindgren reports, regarding Surveys in the Snake Valley, the following:

"This reconnaissance was carried on near the line where the great Columbia lava flows rest against the older ranges of granite and slate in the Idaho side, and showed that the cause of the great fresh-water lake was to be found in the immense lava masses barring the comparatively narrow outlet of a wide pre-Neocene valley. It was also found that since Neocene times the Snake and Salmon rivers have cut gorges from 4,000 to 6,000 feet deep through these lava barriers, equaled in grandeur by few canyons of the West." In the Silver City mining district "transformation or pseudomorphism of a primary gangue mineral, probably calcite, to quartz was noted." Also, "quartz deposits were found carrying gold and silver and at the same time including imprints of vegetable organisms—a proof of their aqueous origin."

Mr. Turner finds in the Yosemite region evidence of "two periods of ice expansion, with an interglacial period."

The Director having, in his capacity as inspector of forest reserves in the northwest, made examination of the Yellowstone, recommends, in his report to the Secretary of the Interior, the construction of new roads from the Grand Canyon Hotel, down the river to Yancey's and thence around the Cook City road; and also several horse trails for the convenience of those who would go on horseback off from the traveled road to points of interest. Another important recommendation is that a hotel be built at the Upper Geyser Basin for the convenience of travelers; and another important suggestion that some means be taken to allay the dust nuisance on the traveled roads in the park.

Mr. Day's report on the Division of Mineral Resources shows a grand total of mineral products of the United States for 1897

to be $632,309,565, "the greatest in the history of the country. A noticeable feature of this remarkable total is the increase in the value of almost all the important metallic products, especially that of pig iron, gold, copper, lead, and zinc, each of the three latter metals reaching their greatest production. Proportionately aluminum made the largest increase, its product being over three times that of 1896 and many times greater than in any year prior to 1895." W.

3. *Pre-Cambrian Fossiliferous Formations;* by CHARLES D. WALCOTT, Bull. Geol. Soc. America, Vol. 10, pp. 199–244, pls. 22–28, 1899.—Mr. Walcott has brought together in this valuable contribution more information than most geologists would suppose to be in existence regarding clastic formations, clearly pre-Cambrian in position, and yet as clearly of sedimentary origin, and probably fossil-bearing, situated in various regions on the North American continent. The discussion of the section of the Belt terrane in Montana is the result of special investigations of the author during a recent trip in that region. The author has gathered the facts from reports already made by others, bearing on this subject, and in discussing the evidence of fossils in strata determined to be of pre-Cambrian age, makes reference to foreign as well as American evidence. The principal evidences brought forward are the following: Of problematic character is Eozoon, whose organic origin is as yet unproven. The same appears to be true of supposed fossil sponges, described by Matthew, from Laurentian rocks of New Brunswick, and of radiolarians and sponges of Brittany.

Graphite has frequently been cited as proof of the existence of fucoids, and the finest example of bedded graphite in Algonkian rocks referred to is at the mines of Hague, on Lake George, New York, where graphite occurs, presenting the appearance of fossil coal beds, and alternating with sandstones. The graphite shale exists, varying from 3–13 feet in thickness.

The supposed organic origin of Paleotrochis is shown to be erroneous by recent investigations of Mr. Diller, as reported in this Journal (May, 1899, p. 337).

Again, the evidence brought forward by Mr. Gresley, of supposed organic remains in the iron-bearing rocks of the Menominee range, Michigan, and described as actual evidence of life, and other evidence of similar kind in these Upper Huronian rocks, have been shown to be of doubtful value upon minute examination.

The Aspidella of the Avalon terrane of Newfoundland is reported by the author as, probably, of organic origin.

The Etcheminian fossils, reported by Matthew, are referred to, without giving judgment in the matter, awaiting the fuller report of the fauna, which is expected soon. Mr. Matthew thinks the fauna contains 20 species.

In the Chuar terrane of the Arizona Grand Canyon series, of established pre-Cambrian age, forms of unquestioned organic origin have been obtained. The one, *Cryptozoon occidentale*, is de-

scribed by Sir Wm. Dawson; the other is described in the present paper under the name of *Chuaria circularis*. Some others, obscure forms, possibly Hyolithes, are associated with them.

The fossils described from the Belt terrane of Montana constitute the more important contributions of this paper. They occur in the "Greyson shales, in a belt of calcareous shales about 100 feet above the Newland limestone, at a horizon approximately 7,700 feet beneath the summit of the Belt terrane at its maximum development. Indications of fossils were first discovered near the mouth of Deep Creek canyon, a short distance above Glenwood postoffice. Subsequently they were found in Sawmill canyon, about 4 miles above Neihart."

"The fauna includes 4 species of annelid trails and a variety that appears to have been made by a minute mollusk or crustacean. There also occur in the same shales thousands of fragments of one or more genera of crustaceans. All the specimens are very much compressed and flattened, and often large fragments of the test have been broken by a movement in the shale subsequent to their embedment in the mud."

"The most interesting feature of the fauna is the occurrence of undoubted organic remains and the presence of a crustacean of a much higher type than most paleontologists would have predicted for this horizon."

Six new species are described from these shales, distributed in three different genera, one of which is a new genus, referred to the Merostomata. W.

4. *A Palæozoic Terrane beneath the Cambrian;* by GEO. F. MATTHEW. Annals N. Y. Acad. Sci., vol. xii, No. 2, pp. 41–56, 1899.—This paper describes a series of strata beneath the Cambrian in New Brunswick, Canada, and Newfoundland, which uncomformably underlie that system. The terrane in Canada is in the southern part of the province of New Brunswick, and is exposed in certain valleys by the erosion of the Cambrian. It consists of red and green slates and sandstones, with some conglomerate at the base, and intercalated. In Newfoundland at Smith Sound, on Trinity Bay, and elsewhere, a similar series of strata are found; but here the strata are almost entirely red slates, though limestone beds are intercalated.

In the limestones there is found a fauna which has notable points of difference from the Cambrian. No trilobites have been found in it, but the Hyolithidæ are especially numerous, and for size exceed all other forms of the fauna. Conical shells resembling Palæacmæa and Scenella are common, but other Gasteropods and the Brachiopods are quite small. A small Lamellibranch was found, and a minute crustacean (Aptychopsis). Burrows and trails of worms occur. Attention is called to the advanced development of the Hyolithidæ which are present in this fauna. It is suggested that some of the red slates near Boston, Mass., may be of this age.

5. *The Islands and Coral Reefs of Fiji;* by ALEXANDER AGASSIZ.—Volume XXXIII of the Bulletin of the Museum of Comparative Zoology at Harvard College has recently been issued, containing a description of the coral reefs of the Fiji Islands by Professor Agassiz, as the result of the investigations begun by him in November, 1897. A paper by the author published in this Journal for February, 1898, gave a summary of his observations, and states clearly the most important point arrived at, namely, his conclusion that the theory of Darwin is inapplicable to these islands. All interested in this fundamental problem will turn with pleasure to this exhaustive monograph, with its beautiful series of one hundred and twenty plates. The earlier of these represent the forms of the islands with their outlying reefs, while nearly one hundred are artotype reproductions of photographs, giving a charming impression of the peculiar features of the beautiful scenery. While this notice can serve only to call attention to the publication of this paper, it may be worth while to quote the concluding paragraph by the author, in which he summarizes the conclusions he has reached:

"My observations in Fiji only emphasize what has been said so often, that there is no general theory of the formation of coral reefs, either of barrier reefs or atolls, applicable to all districts, and that each district must be examined by itself. At least such has been my experience in the Bermudas, the Bahamas, Cuba, Florida, the West Indies, the Sandwich Islands, and Australia. The results of this trip show plainly that Darwin's theory is not applicable to the Fiji Islands, notwithstanding the borings at Funafuti, and that, in all cases I have examined, the reefs form but a thin crust upon the underlying base, the shape and composition of which is not in any way due to the growth of corals of the existing period."

6. *Experimentale Untersuchungen ueber die Bildung der Minerale im Magma von* J. MOROZEWICZ. Tsch. Min. Petr. Mitth., xviii, Nos. 1, 2, 3, 1898.—By their publication in German the important investigations which Morozewicz has been conducting for five years or more and which, as heretofore published in Russian, have been inaccessible to most petrographers and chemists, are now available for use and study.

Not since the now classic studies of Fouqué and Michel-Lèvy has so important a work appeared on the formation of minerals in molten magmas. The author obtained the use of a portion of one of the furnaces in a glass factory and was enabled to conduct his experiments under conditions and on a scale which no previous experimenter had been enabled to command. For the actual results themselves the original work must be consulted, they are too numerous and important to admit of mention in a brief notice. Among others, most of the natural lavas, including rhyolite, as well as a large number of minerals, some of them supposedly foreign to igneous magmas, were produced. The minerals of granite rocks, quartz, feldspar and mica, were formed in dry

fusion. Many laws concerning the formation of minerals in certain chemical compositions by fusion are announced. It is a work which should be carefully studied by every petrographer, mineralogist and mineral chemist. L. V. P.

7. *Kyshtymite and Corundum-Syenite.*—In the work mentioned above Morozewicz describes massive rocks from various localities in the Urals containing corundum. Some of these are corundum-syenites consisting mainly of orthoclase, biotite and corundum—the latter playing the function of quartz in a granite. Some are pegmatitic in character, the well-formed corundum crystals surrounded by orthoclase. Such occurrences must resemble the corundum-syenites of Ontario which have recently attracted much attention. Corundum-syenite-pegmatite occurs also in Montana at an undescribed locality, while Mallet in a recent work (Records Geol. Surv. India) describes instances of corundum in syenitic rocks as well as basic ones, and these latter recall the North Carolina localities. The occurrence of corundum as an important constituent of igneous rocks is now not only well confirmed but proving not uncommon.

Morozewicz describes also from the Urals rocks which consist of corundum and biotite with some zircon and spinel and of granitic structure. The alkali feldspars are here replaced by plagioclase and for these plagioclase-corundum rocks he proposes the name of Kyshtymite. It is the source of the disputed barsowite of Rose, which is here shown to be anorthite. L. V. P.

8. *Le Gabbro du Pallet et ses Modifications*, by A. Lacroix. Bull. des services Carte géol. de France, No. 67, vol. x, 1899, 8°, pp 56, Paris.—The author in this work describes a massif of gabbro surrounded by mica schists. It is formed in the main of an olivine-gabbro with labradorite which passes gradually into norite with andesine and cordierite, especially at the borders. It is cut by numerous dikes whose rocks recall those associated with the gabbros of the Odenwald. The chief interest centers in the origin of the norite with cordierite and garnet, and this is believed to be the result of the normal gabbro coming in contact with the mica schists and absorbing them in quantity with consequent change in chemical composition and production of a different mineralogical type. L. V. P.

9. *Steinbruchindustrie und Steinbruchgeologie;* by O. Herrmann. 8°, pp. 428, pl. 7. Berlin, 1899.—This work, which is written for those using stone in technical ways such as quarrymen, architects, engineers, etc., gives in a rather simple and elementary manner a description of the chief rock-making minerals followed by an account of the most important rocks from a technical standpoint, the descriptions and classification being based on Zirkel's manual. A considerable amount of geology relating to the subject is incorporated. This is followed by a description of the tools and methods of quarrying and working stone.

The succeeding and larger part of the volume is devoted to a

minute description of the quarries and stone industry of the kingdom of Saxony.

The volume should answer the same purpose in Germany that the admirable hand-books of Merrill have done in this country.

L. V. P.

10. *Studies in the Amphiboles and Pyroxenes.*—Attention must be called to two important articles published by R. A. Daly in the *Proceedings of the American Academy*, volume xxxiv. The first (pp. 311–323) gives a minute discussion, with several plates, of the optical characters in the vertical zone of amphiboles and pyroxenes, showing with this a new method of determining the extinction-angles from cleavage plates.

The second, a larger paper (pp. 373–429, pl. i–iv), takes up the subject of the etching figures of these minerals, particularly those of the amphibole group. The care with which the author has worked out the special conditions necessary to obtain the best results and the fullness with which he describes his experiments, make his paper of great value to all interested in this subject, aside from the conclusions which he has deduced. Among other points he proves that the amphiboles are throughout holohedral. He also shows that this method of investigation serves to exhibit the close relationship existing between the different members of the group, as too between them and the corresponding pyroxenes. Further, it emphasizes the distinction between the non-aluminous and aluminous amphiboles, usually insisted upon in works on mineralogy, and at the same time shows the great importance of a sesquioxide, whether ferric oxide or alumina. In regard to certain members of the amphibole group, the following conclusions are given:

"Glaucophane and gastaldite are the same species, and both isomorphous with hornblende. Arfvedsonite appears to hold a more or less independent place in the family of amphiboles. Barkevikite is more closely related to common hornblende than to arfvedsonite. Anthophyllite and gedrite are plainly orthorhombic and holohedral. Aenigmatite diverges considerably from the amphibole habit, but betrays a tendency toward symmetrical cohesional property, as it does toward crystallographic symmetry." Incidentally the author has found an amphibole so peculiar in etching figures that he has separated it as a special variety under the name *philipstadite*. (See p. 83.)

11. *Brief Notices of Some Recently Described Minerals.* Hardystonite is a new calcium-zinc silicate from Franklin Furnace, New Jersey, described by J. E. Wolff. It occurs in granular crystallized form, showing several cleavages interpreted as basal and prismatic. Thin sections show it to be uniaxial and negative. Hardness, 3 to 4; specific gravity, 3·396; colorless to white, with vitreous luster. The formula deduced is $Ca_2ZnSi_2O_7$, obtained from a number of analyses, of which one is here quoted.

SiO_2	ZnO	MnO	CaO	MgO	Fe_2O_3	ign.
38·10	24·30	1·50	33 85	1·62	0·57	0·52 = 100·46.

Before the blowpipe it fuses with difficulty to a cloudy glass, giving a red calcium flame; on charcoal it glows and yields a sublimate of zinc oxide; gelatinizes easily with hydrochloric acid. Obtained from the North Hill mine at Franklin, where it occurs in a fine granular banded ore associated with willemite, rhodonite and franklinite. Named from the township in which the locality is situated.—*Proc. Amer. Acad. Sci.*, xxxiv, 479, 1899.

CARNOTITE is a vanadate of potassium and uranium described by C. Friedel and E. Cumenge. It occurs as a yellow crystalline powder, or in loosely cohering masses, easily separated by the fingers; it is intimately mixed with a quartzose sand. The formula given for it is $K_2O.2U_2O_5.V_2O_5.3H_2O$, deduced from the following analyses (after the separation of silica) of air-dried material:

V_2O_5	U_2O_3	K_2O	H_2O	
20·12	63·54	10·37	5·95 = 99·98	
20·31	64·70	10·97	5·19	Fe_2O_3 0·96 = 102·13
19·95	62·46	11·15	—	Fe_2O_3 0·65

Occurs in Montrose Co., Colorado, in cavities or associated with malachite and azurite. Some samples show 60 p.c. of SiO_2, the purest 2·6 to 7·2 p.c.; separation is accomplished by nitric acid. Named after M. Adolphe Carnot.—*Comptes Rendus*, cxxviii, 532, 1899.

PHILIPSTADITE is a variety of amphibole named by R. A. Daly, and identified by him in the course of an investigation of the etching figures of the amphiboles, which is referred to in another paragraph (p. 82). The locality is Philipstad, Sweden. It shows anomalous etching figures on *m* (110) and *b* (010); pronounced zonal structure; small optic axial angle (about 50°); also unusual pleochroism and absorption: viz., **a** light brownish green, **b** dark yellow-green, **c** dark blue-green; $\mathbf{b} > \mathbf{c} > \mathbf{a}$. It is optically −, with an extinction-angle on *b*(010) with $c = +15° 9'$ (Na). An analysis by Pisani gave:

SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	CaO	MgO	Na_2O	K_2O	ign.
45·20	0·84	7·34	7·55	15·80	1·52	12·30	8·40	0·80	0·37	0·70 = 100·82

—*Proc. Amer. Acad. Sci.*, xxxiv, 433, 1899.

FEDEROVITE is a pyroxene, intermediate between ægirite-augite and ægirite. It is named by Viola in a petrographical article on rocks from the province of Rome, Italy, in which the author makes an extended study of the optical properties of the pyroxenes. In this he shows that they may be classified into groups according to the angle, $c \wedge \mathbf{c}$ which angle increases with increasing soda and iron. Of those in which $c \wedge \mathbf{c} = 50°–56°$ and $2V = 50°$ are called aegirite-augite, he thinks that those in which $c \wedge \mathbf{c} = 65°–75°$ and $2V = 50°$ should have a separate name. Such a variety would contain from 9–13% alkali, about 24% iron oxide and strong pleochroism $\mathbf{c}$ = yellow, $\mathbf{b} = \mathbf{a}$ = olive green. The name given above, which is proposed for this variety, is given after the Russian petrographer E. von Federov.—*Jahrb. f. Min.*, i, 120, 1899.

12. *The Characters of Crystals; an Introduction to Physical Crystallography;* by ALFRED J. MOSES. Pp. 21, New York, 1899. (D. Van Nostrand Company.)—Professor Moses has here developed and presented in book-form a series of chapters on the Geometrical and Physical Characters of Crystals, the substance of which has already appeared in the School of Mines quarterly. The first part of the work is devoted to the geometrical side, and after a brief historical summary, there is given an account of the general properties of crystals, followed by a discussion of the thirty-two groups divided according to symmetry. Here the order, method and nomenclature of Groth are followed closely. The latter half of the work is devoted to physical characters, those relating to light occupying by far the larger portion of the space. The presentation throughout is concise and in the main simple; many students will find the work interesting and helpful, for it does not assume a special knowledge of Mineralogy.

III. BOTANY.

1. *Variation under grafting, and the heredity of acquired characters;* by L. DANIEL. *Ann. sc. nat., April and May,* 1899.—M. Daniel has conducted his interesting studies in regard to the effect of the scion on the stock and the origination of variation thereby, for almost ten years. He has made his work logically comparative, and has, in this way, contributed some very important facts to the literature of the subject. He insists that a broad distinction must be drawn between the behaviour of a cutting and an implanted graft. The former has in the soil the nutritive conditions of its parent; the graft is tributary at once to the stock in which it is fastened and places it at once under contribution. It is not a matter of parasitism, for the scion, with its leaves, is to aid in providing elaborated matters for the stock, but, nevertheless, it demands crude materials from the soil through and from the stock.

The graft and grafted plant must be regarded as a case under the general law that change of environment may, or rather, must modify form and structure. Variation from grafting is a function of modifications brought about in the general nutrition of the two plants. This modification may be direct as in the case of the somatic union, or indirect as in the instance of the blending of the germ-plasma from two sources. The author makes the statement that the germ-plasma can be affected from the first generation in the graft, contrary to the law laid down by Weissmann.

The graft and stock introduce variations which may be very slight and liable to be overlooked, but carefully considered these variations are seen to be generally conservative. And as the graft can convey in perpetuity an accidental variation, these accidental variations of the second order can themselves be transmitted effectively. If the influence of a graft on a plastic soma

may be strong enough to lead to the origination of a variety, as this research has shown to be possible, we have here in the process of grafting a valuable appliance which is capable of wide utilization in initiating new forms as well as in preserving old ones. The action of grafting on the reproductive elements and on the transmission of these new characters opens up to seed cultivators an inviting field of practice. It must not be overlooked that, as matter of fact, variation does not come in the grafted plants themselves, but manifests itself in the embryo alone. The author emphasizes the importance of this process of grafting in the improvement of sorts, and shows that such work can be carried on with the utmost system. The process is, by no means, confined to woody plants, but, as the investigation shows abundantly, it is applicable to a wide range of herbaceous species. Merely from a utilitarian point of view, the research is a valuable contribution, while regarded from a purely scientific standpoint it possesses deep interest. The work already done is of consequence, but its best service is in opening up new practical questions. G. L. G.

2. *Researches concerning certain features in the appropriation of nitrogen by plants;* by L. Lutz. *Ann sc. nat., Jan. and Feb.*, 1899.—After a good, although brief, resumé of the more important studies in regard to the relations of plants to nitrogen, the investigator gives a detailed account of his own researches in one part of the field. His results are claimed by him to prove that placed under as aseptic conditions as possible, and also under conditions which forbid ferment action or the fixation of free nitrogen, phanerogamic plants can borrow from *amines* employed in the form of salts, all the nitrogen which is necessary for their use. And, further, he decides that the assimilation of these substances can take place without having their nitrogen previously brought into nitric or ammoniacal combination. There is, however, a condition requisite, namely: that the *amines* arise from the substitution of hydrogen in radicals which do not possess too great size of molecule; thus, the methylamines are excellent sources of assimilable nitrogen, while benzylamine and pyridine are inadequate. The phenol amines are tonic.

The salts of the compound ammoniums and the alkaloids, employed as the exclusive source of nitrogen, do not furnish enough to plants; on the contrary, plants under these conditions may even lose a part of their initial nitrogen. This loss may be interpreted, according to the author, as due to a sort of auto-fermentation.

One of the most interesting facts noted by M. Lutz is the ready absorption of unassimilable alkaloids in the presence of assimilable nitrogen. Possibly, he says, this may throw light on the cause of the migrations and disappearance of alkaloids in the plant at certain epochs of its life.

The whole series of experiments on three classes of plants, Phanerogams, Algae, and Fungi, shows that these organisms are

capable of appropriating the lower animes as well as the nitrates, and this conclusion is emphasized as explaining the rapidity with which plants can utilize manures. The author points out the difficulty of conducting such experiments on phanerogams, but the results thus far are the same as those obtained by study of fungi, which can be more easily managed. G. L. G.

IV. Miscellaneous Scientific Intelligence.

1. *American Association for the Advancement of Science.*—The preliminary announcement of the forty-eighth annual meeting of the American Association has recently been issued. The meeting will be held at Columbus, Ohio, August 21st to 26th. The several affiliated scientific societies will also hold their sessions in Columbus. The Association headquarters will be located in room 10, University hall, Ohio State University, and the hotel headquarters of the Council of the Association will be at the Chittenden Hotel. The local secretary is Professor B. F. Thomas, Ohio State University, Columbus, Ohio, who should be addressed in regard to all matters relating to local arrangements, transportation, and hotel and boarding-house accommodations, etc.

The Permanent Secretary, Mr. L. O. Howard, of Washington (Cosmos Club, before August 15, after that date A. A. A. S., Columbus), who issues the circular alluded to, will send copies of it to all desiring information in regard to the presentation of papers, the nominations for membership, etc.

2. *Scientia.*—A new series of small volumes on scientific subjects has been undertaken by G. Carré & C. Naud, as publishers, in Paris. It is intended to present in concise form discussions of scientific questions of importance at the present time with the object of aiding the busy reader and worker to keep up with the bewilderingly rapid progress of science.

The series is divided into two parts,—*physico-mathematical* and *biological.* The character of the work that will be done is sufficiently guaranteed by the names of those that appear as directors in the two departments. They are as follows: In the physico-mathematical section:—MM. Appell, Cornu, d'Arsonval, Friedel, Lippmann, Moissan, Poincaré, Potier. Also, in the biological section—MM. Balbiani, prof. au College de France; d' Arsonval, Filhol, Fouqué, Gaudry, Guignard, Marey, Milne-Edwards.

Three volumes have been issued, whose titles are given below. Among others proposed is one on the Zeeman Effect, by A. Cotton; another on the Determination of the Ohm, by G. Lippmann, etc.

The volumes already published are:—

La théorie de Maxwell et les oscillations Hertziennes. H. Poincaré: pp. 80.

La Spécificité cellulaire. L. Bard. pp. 100.

La Sexualité. F. le Dantec. pp. 98.

3. *Annals of the Astronomical Observatory of Harvard College.* Volume XXXIX, Part I. *Peruvian Meteorology*, 1888 to 1890. Compiled and prepared for publication by SOLON I. BAILEY, under the direction of E. C. Pickering, Director.—This very interesting volume contains an account by Professor Bailey of the establishment, under the auspices of the Boyden Fund, of a meteorological station on the volcano El Misti, above Arequipa, Peru, at an altitude of 19,200 feet. Professor Bailey's narrative is most entertaining and, in connection with the excellent illustrations, gives those who are not so fortunate as to have had the opportunity to attain such an altitude, some idea of the grandeur of the accompanying scenery. A second chapter discusses the configuration and height of the Andes and a third contains a series of tables giving the meteorological observations made in Peru during the years 1888, 1889, and 1890.

4. *Report of the Superintendent of the United States Coast and Geodetic Survey, showing the progress for the year ending June, 1897.*—The annual report of General W. W. Duffield has recently been issued by his successor, Mr. Henry S. Pritchett. It contains the usual statement of the progress made in the Survey work at different points on the coast, with a series of fifteen charts relating thereto. The second part of the volume contains a series of twelve Appendices on various topics, among which we note one on the Distribution of Magnetic Dip and Intensity for January, 1890, by C. A. Schott (second edition, with three charts); another by the same author discusses the telegraphic longitude net of the United States, and its connection with that of Europe from 1866 to 1896. Another contains an account of the Magnetic Observations made in connection with the Greenland Expedition of 1896, under the charge of Professor A. E. Burbon, given by G. R. Putnam. Two highly valuable papers by Rollin A. Harris contain a Manual of Tides in two parts,—the first dealing with the history of the subject, the second with tidal observations, equilibrium theory, and harmonic analyses. The fullness of these discussions and the large number of illustrations make this memoir particularly serviceable.

5. *A Catalogue of* 2,030 *Stars for the epoch* 1895, *with an Appendix giving the derivation of proper motion for* 971 *Stars*; by JERMAIN G. PORTER, Director. Publications of the Cincinnati Observatory, No. 114, pp. 114, 4to. Cincinnati, 1898.—This important catalogue containing a second series of five-year observations, with Cincinnati meridian circle by the Director of the Observatory, J. G. Porter, has recently been issued.

6. *Stars and Telescopes. A Hand-book of Popular Astronomy;* by DAVID P. TODD, Director of the Amherst Observatory; pp. 419, with 244 illustrations, including 82 portraits. Boston, 1899. (Little, Brown & Co.) This book is founded on Lynn's Celestial Motions with copious additions by Dr. Todd, especially in the matter of illustrations. In so long a list there are naturally some to be found which could well enough be spared, as drawings of

the supposed markings of Mercury and Venus, and photographs of such mechanisms as the bolometer in a water-jacket and the 40-foot horizontal photo-heliograph in its shed—the view being taken from outside the shed.

Such superfluities do not detract from the value of the book, which is crowded with varied information most attractively presented. W. B.

7. *Elements of Practical Astronomy;* by W. W. CAMPBELL, Lick Observatory; pp. 264. New York, 1868. (Macmillan & Co.) Based on lectures delivered at Michigan University. A very clear and scientific presentation of as much of the subject as is possible or desirable in training students upon the fundamental principles of telescopic measurements. W. B.

8. *An Introduction to the Mathematical Theory of Attraction;* by FRANCIS A. TARLETON, Professor of Natural Philosophy in the University of Dublin; pp. 290. New York, 1899. (Longmans, Green & Co.) The theory of attraction, which had its origin in physical astronomy, now finds its more difficult and important uses in electricity and magnetism. As the author points out in his preface, the theory of fluid motion, investigated with such far-reaching results by Helmholtz, Thomson and Stokes, has its leading problems mathematically the same as problems in the theory of attraction. The present text-book gives adequate treatment of the theory in its applications to these lines of research. W. B.

9. *Les Variations de Longueur des Glaciers dans les Régions Arctiques et Boréales;* by CHARLES RABOT.—In the number of this Journal for November, 1897, an abstract was given of the first part of a memoir on the above subject, published under the auspices of the Commission Internationale des Glaciers. The opening portion of the second part is now published in the number of the *Bibliothèque Universelle* for April 15th. It is chiefly occupied by a discussion of the glaciers of Spitzbergen as observed by various explorers, and gives many interesting facts in regard to this remote region.

10. *The Odonata of Ohio;* by DAVID S. KELLICOTT, Ph.D. pp. 116. Columbus, 1899. Ohio State University. Contributions from the Department of Zoology and Entomology. No. 1.—This valuable paper by the late Professor Kellicott (died April 13, 1898) has recently been issued. It has been edited by Mr. J. S. Hine, who has completed the parts of the manuscript left unfinished; he has also added a sketch of the author's life and a bibliography. The drawings have been made by Mr. W. E. Kellicott.

11. *Electricity in Town and Country Houses;* by PERCY E. SCRUTTON. Second edition, pp. 148. Westminster, 1898. (Archibald Constable & Co.)—This little volume, of which a second edition is now issued, gives an account of the methods employed in installing electricity in houses, with numerous practical illustrations. Besides the application of electricity to lighting, it also discusses briefly some of the various other uses, as a motor, etc., to which it is adapted.